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ABSTRACT

This manual was designed for use in conducting staff development sessions for elementary school teachers of science in Mississippi in grades K-6. Included in the document are activities that were intended to model, where possible, exemplary teaching practices based upon research related to the cognitive development of children. Ten topics are treated in this manual. The number of instructional hours necessary for completing the workshop activities for each topic varies from 2 to 12 hours. It is recommended that topics 1 through 3 be presented in sequence. Topic 1 establishes the rationale for hands-on science, drawing upon research related to how children learn. Topic 2 introduces the basic processes of science, which should be emphasized in kindergarten through third grade in preparation for work with the integrated processes (topic 3) in the upper elementary grades. The remaining seven sections deal with: (1) teacher questioning techniques; (2) evaluation; (3) effective use of textbook materials; (4) the acquisition and management of elementary school science materials; (5) the outdoors as an extension of the classroom; (6) an interdisciplinary approach to teaching science; and (7) classroom management and safety in elementary school science. Curricular materials on magnets and graphing are presented in two appendixes. (TW)

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STAFF DEVELOPMENT PROJECT

MATHEMATICS / SCIENCE

GRADES K - 6

MACTE

MISSISSIPPI ASSOCIATION
OF COLLEGES FOR
TEACHER EDUCATION, INC.

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PREFACE

This manual was designed for use in conducting staff development sessions for elementary school teachers of science in grades K-6. In the development of the manual, science was viewed not simply as a body of knowledge, but as an ongoing process in which everyone engages as they attempt to organize and systematize objects and events encountered in their environment. Strategies for teaching science which reflect this view and are soundly based upon research related to the cognitive development of children are emphasized. The intent was to model in these staff development activities, wherever possible, exemplary teaching practices for elementary school science. For these reasons, a heavy emphasis was placed on hands-on science activities, social interaction in small groups, and teacher-guided discussion to summarize, clarify, and accurately verbalize the abstraction and/or correct errors in thinking.

Ten topics are treated in the manual. The number of instructional hours necessary for completing the activities for each topic varies from two-twelve hours. The entire instructional program may require from 40-60 hours, depending upon the skill and knowledge base of the participating teachers.

In the use of the manual, it is recommended that Topics One through Three be presented in that ordered sequence. Topic One establishes the rationale for hands-on science, drawing heavily on research related to how children learn. Topic Two introduces the basic processes of science, which should be emphasized in kindergarten through third grade in preparation for work with the integrated processes (Topic Three) in the upper elementary grades. The processes of science are viewed as the vehicle through which conceptual understanding of scientific knowledge is developed. After working through the first three topics, teachers should have a better understanding of the nature of science and the need for a shift in emphasis from memorization of science content to development of higher level thinking skills. After developing the rationale for hands-on science and use of the processes, the remaining topics in the manual may be addressed in any order.

The manual was written as an instructional guide for a staff development leader. Each topic begins with a brief overview followed by a series of instructional activities. For each activity, the workshop leader's behaviors are listed in summary form followed by the instructional materials to be used and a description of advance preparation. In a section labeled "Teaching Sequence," detailed teaching plans are developed. Various types of teaching aids, worksheets, record sheets, activity cards, and masters for transparencies, are incorporated in the manual for each topic. Since most of the instructional activities require the hands-on manipulation of materials, a maximum of thirty teachers per workshop session is recommended.

The manual addresses areas of need in teacher education identified by science educators across Mississippi, grade school through higher education levels. Science in the elementary grades has long been a neglected area in Mississippi schools -- indeed in the nation, as emphasized in the report A Nation At Risk, by the Commission on Excellence in Education. Problems of inadequate teacher training for science instruction and the tendency of many school districts to treat science as a poor relation when compared to reading and mathematics are often cited as problems that interfere with the effective teaching of science at the elementary school level. At a time in history when science and technology are dominant forces in the world economy and our very survival depends upon better understanding of the environment, the loss in human and economic potential because of scientific illiteracy in our state is immeasurable.

Science well taught in the elementary grades builds the thinking skills, conceptual mental structures, and positive attitudes necessary for a lifetime in the "search for regularities" (Kauchak & Eggen) which best defines science. If somehow this staff development program promotes the teaching of science in the elementary grades in a less authoritarian approach, which, in the words of Paul DeHart Hurd "does much to close minds, not open them; to make robots, not thinkers; to discourage, not encourage further work in science; to inhibit, not promote attempts to apply scientific methods to the numerous problems one meets daily in every walk of life," we, as educators, can rejoice in a job well done.

Iva D. Brown

Kauchak, Donald and P. Eggen, Exploring Science In The Elementary Schools. Chicago: Rand McNally College Publishing Company, 1980, p. 7.

Hurd, Paul DeHart, "Biological Education In American Secondary Schools." BSCS Curriculum Studies Bulletin No. 1. Washington, D.C.: American Institute of Biological Sciences.

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TABLE OF CONTENTS

TOPIC 1: INTRODUCTION TO HANDS-ON SCIENCE 1

Activity 1: Observing and Classifying Rocks
Activity 2: How Children Learn Science

TOPIC 2: EXPLORING THE BASIC SCIENCE PROCESSES 49

Activity 1: Introducing the Basic Science Processes
Activity 2: Using the Basic Science Processes in Hands-On Activities
Activity 3: More Involvement in Using the Basic Science Processes in Hands-On Activities

TOPIC 3: EXPLORING THE INTEGRATED SCIENCE PROCESSES 97

Activity 1: Experimenting With Swinging Pendulums
Activity 2: Controlling Variables -- Upward Movement of Liquids in Materials
Activity 3: Asking Appropriate Questions for Experimenting
Activity 4: Stating Hypotheses
Activity 5: Operationally Defining
Activity 6: Organizing and Interpreting Data: Key Number
Activity 7: Constructing and Interpreting Graphs

TOPIC 4: TEACHER QUESTIONING TECHNIQUES 151

Activity 1: Specific Techniques for Improving Your Questioning Skills
Activity 2: Phrasing and Sequencing Questions to Guide Thinking

TOPIC 5: EVALUATION IN SCIENCE 176

Activity 1: Information on Evaluation Techniques
Activity 2: Evaluation Techniques for Specific Activities

TOPIC 6: EFFECTIVE USE OF TEXTBOOK MATERIALS 210

Activity 1: The Nature of Reading Processes
Activity 2: Procedures for Analyzing Texts
Activity 3: Analysis of a Passage from a Science Text
Activity 4: Guiding Reading Assignments

TOPIC 7: ACQUISITION AND MANAGEMENT OF ELEMENTARY SCHOOL SCIENCE MATERIALS 262

Activity 1: Pardon Me, But Your Ingenuity is Showing
Activity 2: Doing Science on the Thinnest of Shoestrings
Activity 3: If I Only Had Some Money!
Activity 4: Investigating Science Topics Using Resource Materials

TOPIC 8: THE OUTDOORS AS AN EXTENSION OF THE CLASSROOM 295

Activity 1: How Plants are Affected by the Environment
Activity 2: Habitat Selection of Pill Bugs (or Sow Bugs)
Activity 3: A Survey of Soil Organisms
Activity 4: Plant Distribution Analysis

TOPIC 9: AN INTERDISCIPLINARY APPROACH TO TEACHING SCIENCE 320

Activity 1: Teaching Science from a Basal Reader
Activity 2: Making Your Science Lesson Come to Life

TOPIC 10: CLASSROOM MANAGEMENT AND SAFETY IN ELEMENTARY SCHOOL SCIENCE 333

Activity 1: Classroom Management Techniques
Activity 2: Safety in the Elementary Science Classroom

APPENDIX A: MAGNETS

APPENDIX B: USMES MATERIAL

TOPIC 1: INTRODUCTION TO HANDS-ON SCIENCE

Jean Shaw
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Because these training sessions focus on hands-on science as an appropriate way of learning, the sessions will feature much work with materials. Participants will work extensively with the science processes-- observing, measuring, communicating, predicting, inferring, classifying, and experimenting--so that they can build their own knowledge of the processes and applications of the processes in the middle grades. Participants will also learn to share their knowledge with other professionals.

The introductory lesson features an observation activity. After unguided initial observations, participants will be instructed to make more extensive observations and share their findings with others. Participants will observe a rock. Rocks are commonly found in the environment. Children are often intrigued by rocks and are eager to examine them closely. Participants will try to classify their rocks as igneous, sedimentary, or metamorphic and answer questions appropriate to their kind of rock. The identification exercise allows participants to use reference materials to gain background information and to use a reference to guide their observations.

Next, participants receive information on how children learn science. This information will serve as a psychological and philosophical basis for the active, hands-on orientation advocated in these training materials for the teaching of science to elementary school children.

The information in this background section could also be used to gain administrative support for hands-on science and to inform parents and citizens about hands-on, process-oriented science. Parts of the material could be used for parent meetings.

ACTIVITY 1: OBSERVING AND CLASSIFYING ROCKS

Start the session with a hands-on activity in which participants can sharpen and refine their powers of observation. Since the main theme of the series of workshops is active involvement in science, it is appropriate to start with a workshop that includes a hands-on activity.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader's behaviors follow:

1. Divide participants into groups of four and have them handle and observe the rocks, then record their observations.

2. Distribute Observation Guide I and instruct participants in its use. Participants should use the guide to refine the observations that they made previously.

3. Invite participants to share observations.

4. Lead participants to break open and examine the insides of their rocks, then briefly share their findings.

5. Distribute rock identification sheets and direct participants to further examine their rocks using information and questions from the sheets.

6. Guide participants to bring rocks together and develop a multi-stage classification system for the set of rocks.

7. Discuss observation and classification skills and have participants give examples of using them.

MATERIALS LIST

For each group of four participants:

1 rock
5 paper towels
3 extra rocks
1 paper bag
1 box of matches
1 100 cm tape measure
1 30 cm ruler

For each participant:

Observation Sheet I
Observation Sheet II
Rock Identification Supplement

11

For the large group to use as needed:

2 hammers
1 balance scale with weights to 500 g
1 magnet
1 dry cell, light bulb, socket
2 hands lenses
pan of water
calibrated volume measure to 500 ml
1 set -- measuring spoons -- 15 ml, 5 ml, 2.5 ml, 1.25 ml
5 sheets of paper for labels

ADVANCE PREPARATION

Gather equipment, reproduce worksheets, study the teaching sequence.

TEACHING SEQUENCE

1. Divide participants into groups of four. Distribute materials (rocks and Observation Sheet I (Teaching Aid 1). Ask participants to examine their rocks and record at least ten properties of the rocks. Point out the additional equipment that is available.

   After participants have completed their recording, ask each group to share one or two interesting observations. Ask: Did any group use a sense other than sight to observe? How? Did any group record a statement that was not gained by firsthand knowledge? (If so, this is not an observation.) What quantitative data were gathered? Did qualitative observations use reference points? What were some examples? How did you act on your object?

2. Distribute Observation Guide I (Teaching Aid 2). Ask participants to make more observations using the guide and Observation Sheet I. (Record additional observations). Point out that the guide includes a caution about direct observations and instructions for multisensory observations. The guide also draws attention to qualitative and quantitative observations. It invites participants to act on objects. (Participants should now use additional equipment more extensively.)

   If no group has determined the volume of their rock, show one group how to do so by water displacement. (Fill a measuring device with water to cover the rock. Read the water level. Submerge the rock. Find the difference between the initial and second reading for the approximate volume of the rock. Later, let that group demonstrate the procedure to all the participants.)

3. Ask participants to share orally several observations they made using Observation Guide I.

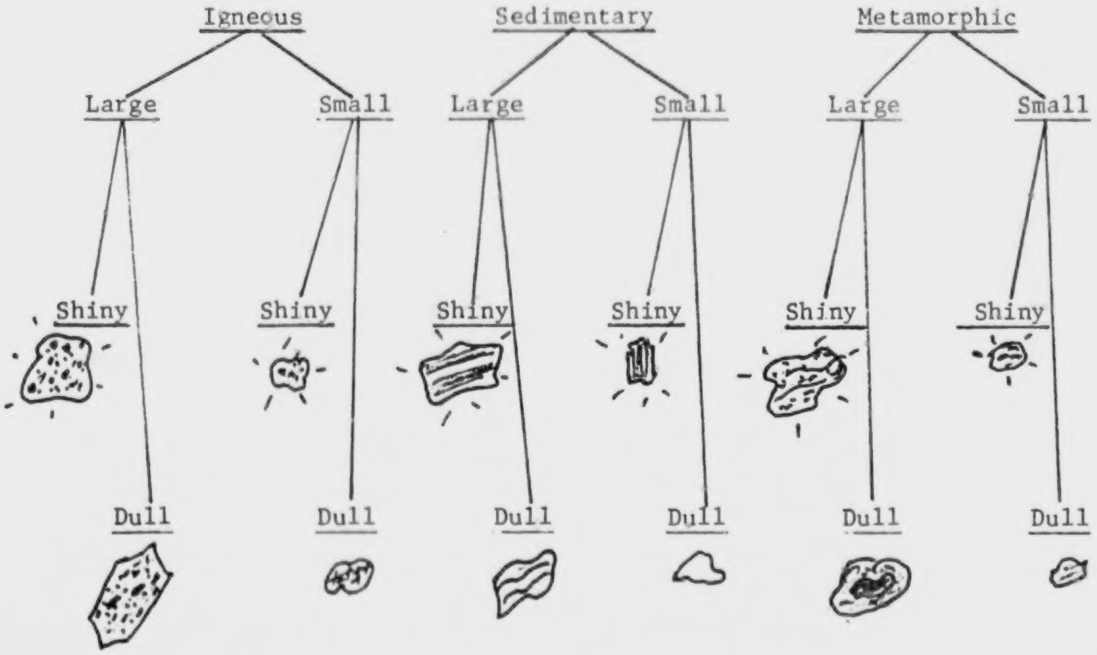
4. Distribute Observation Sheet II (Teaching Aid 3) and ask each group to record some predictions about what the inside of their rock will look like and what will happen to their rocks when they are broken

with a hammer. Instruct the groups to wrap their rocks in paper towels, then place them in a paper bag. Let the groups take turns breaking their rocks with a hammer. Stress safety precautions--be careful of swinging hammers; be sure rocks are securely wrapped to avoid flying particles. Try to leave some large pieces of rock.

Let each group examine their broken rocks and compare their predictions to their findings. Encourage groups to use Observation Guide I. Orally share some observations, especially unusual or unexpected findings.

5. Distribute the Rock Identification Supplement (Teaching Aid 4). Have each group try to identify their rock, use the questions on Observation Guide II (Teaching Aid 5), and record several statements about their rocks on Observation Sheet II. Briefly share findings.

6. Have participants bring their rocks together and place them on a central table. Introduce several extra rocks. Ask participants to classify the additional rocks as igneous, sedimentary, or metamorphic. Ask participants to physically place the rocks in three groups and add labels to the three categories. Now ask participants for additional characteristics by which they could make subgroups of rocks. For example, you might add the subclassification of larger (over 8 cm across) and smaller rocks. Physically rearrange the rocks to accommodate the new subclassification. Add appropriate labels. Use at least one more subclassification such as color--bright or dull. Add labels for this subclassification. Your rocks might look like this:



Working with young children, teachers would probably not start grouping rocks as sedimentary, igneous, and metamorphic. They might start with large and small and add just one subclassification such as shiny and dull or dark and light. Young children might also deal with classification systems using terms such as one color or several colors, rough and smooth surfaces, or sharp edges and rounded edges.

Ask: How else might you have started to classify the rocks? What other subclassifications might you have used?

7. Observing and classifying are skills that are important in students' everyday lives,as well as in reading and math. Children observe letters, words, pictures, charts, and graphs as they learn to make sense of reading material. Children observe and manipulate objects or pictures of objects constantly in mathematics. Their understanding of words, numbers, and concepts is dependent to a large degree on past experience which includes observation and classification of objects.

   Many teachers who receive inservice training using materials from this lesson also teach language arts and reading, math, and social studies. How can the skills of observation and classification be utilized and extended in these subjects? (Have participants give some specific examples.)

OBSERVATION SHEET I

List at least 10 observations of your object.

Teaching Aid 1

OBSERVATION GUIDE I

1. Be sure to include only properties that can be directly observed. Do not use past experience. For example, if you state "the rock will not burn," you must have actually and directly observed this.

2. Use as many senses as are appropriate to observe your object. (You may need to direct students about when tasting is appropriate.) Since most people tend to rely heavily on sight, be aware of what you can learn about your object using your senses of touch, hearing, smelling, and tasting.

   For young children, adults are wise to use only materials that can be safely smelled and tasted or to supervise closely when materials that taste unpleasant are used. Older children should be taught to smell chemicals with caution, and not taste unfamiliar substances.

3. Include quantitative data about your object. This involves measuring your object. What linear dimensions has your object? What is its weight? Volume? Quantitative measures help us to be precise in describing properties of objects.

4. Include qualitative data about your object. This may include statements about its size, shape, texture, color, taste, brittleness, solubility, and other qualities. Reference your qualitative observations. Rather than stating that an object is large, tell what it is larger than (smoother than..., harder than ...).

5. Include some observations where you have acted on the object. Will it roll? float? burn? dissolve? conduct electricity? attract to a magnet? react with acid or alkaline substance?

   Note that children may need some rules for observing objects and specimens. Many objects may be manipulated without destroying them. It may be permissible to cut or pull other objects apart. Living specimens should be treated with respect.

Use the questions and statements given above to refine your initial observations by redoing, adding to, or deleting observations from Observation Sheet I.

OBSERVATION SHEET II

Predictions about the inside of your rock.

Observations about the inside of your rock. (Use Observation Guide I to check the quality of your observations.)

Rock Identification

A rock is a solid fragment of the earth, and is usually composed of two or more minerals. There are three general categories of rocks: igneous, sedimentary, and metamorphic. The categories are determined by the way in which the rocks formed.

Each category presents unique problems when one tries to identify a rock sample.

IGNEOUS ROCKS

Igneous rocks form directly from magma deep underground or at the surface. These rocks can be classified by composition and texture.

Composition refers to the kinds of minerals found in a rock. Texture indicates the size of individual minerals in a rock.

As magma cools minerals crystallize until the material has solidified. Therefore, the composition is determined, in part, by the original content of the magma. Texture is influenced by a complex relationship between rate of cooling and temperature. Each mineral forms within a given temperature range. If magma remains at a given temperature for a longer period of time a mineral will have more time to grow larger.

There are three textures of igneous rocks. Coarse-grained rocks have large, easily seen crystals. Granite is a common example of this texture. Rhyolite, a fine-grained rock, has very small crystals best seen with a microscope. The third texture, glassy, is represented by obsidian. In this case, magma had cooled so fast that no minerals were able to form. For this reason obsidian does not fit the definition of a rock.

Gabbro has the same texture as granite, but has a different composition. Basalt is fine-grained, as is rhyolite, but their compositions are different.

Over 600 igneous rocks have been identified. Only a few of those are considered common.

SEDIMENTARY ROCKS

When rocks are exposed to the atmosphere and water the minerals begin to breakdown. This could be due to chemicals in the air, water or soil. Or, it could be due to a physical force. These processes are chemical and mechanical weathering.

Weathering minerals are fragmented and carried away from the base-rock by wind, running water, and gravity. The fragments become smaller as weathering continues. Eventually the particles, called sediments, are deposited and buried. Sediments are compressed and cemented together in a variety of ways to form sedimentary rocks.

Sediments can also be the result of chemical reactions. Precipitation in water can produce sediments which settle and form layers. The remains of marine animals and algae containing calcium form thick deposits which eventually become limestone.

Sedimentary rocks often exhibit layers, called strata, as a result of deposition of particles. These strata are not necessarily present in a sedimentary rock especially if the specimen is small.

Sandstone, a common sedimentary rock, is composed of sand-size particles, but can be soft and easily broken or very hard.

Limestone, another common sedimentary rock, often contains the fossil remains of marine animals.

METAMORPHIC ROCKS

Metamorphic rocks are the result of changes in pre-existing rocks by the influences of heat, pressure, and chemicals. The pre-existing rocks might be igneous, sedimentary, or other metamorphic rocks.

The changes are often noticeable as new minerals which are not found in the other types of rocks. Distorted layers of minerals, called foliation, are sometimes visible as evidence of great pressures which changed the rock. A small sample of a metamorphic rock might not exhibit foliation.

Examples:

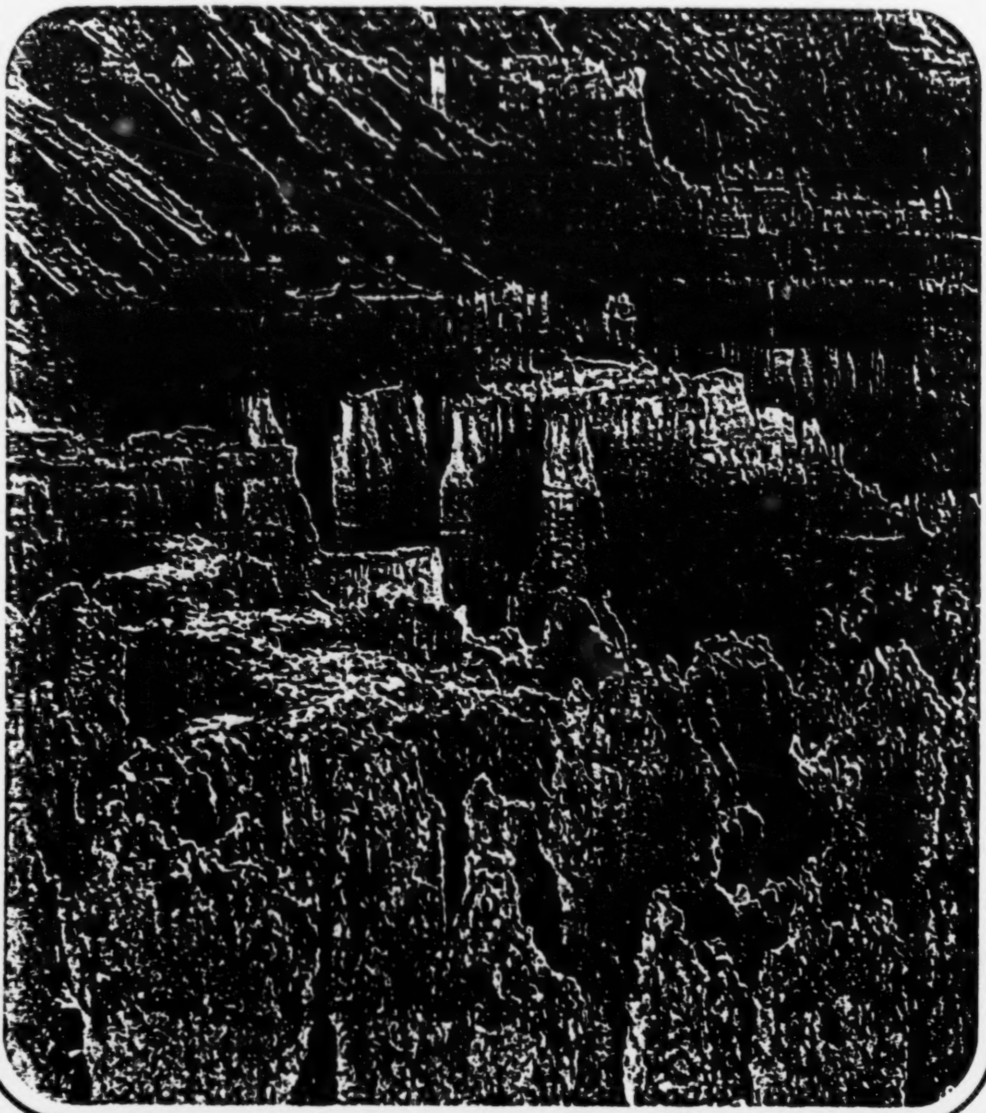
Igneous	Sedimentary	Metamorphic	
Granite		Gneiss	
	Sandstone	Quartzite	
	Limestone	Marble	
	Mudstone	Slate	Schist

Topic 1/Activity 1
Teaching Aid 4, Cont.

Chapter Two

Rocks

How would you describe these rocks?
Where might you go to see such rocks?
How do you think they were formed?



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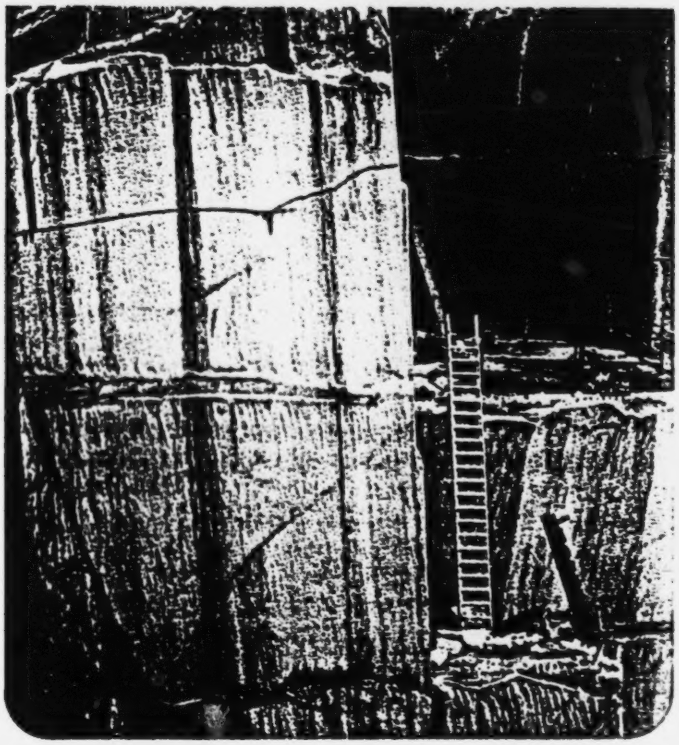
Topic 1/Activity 1
Teaching 4, Cont.



Many places have beautiful scenery. Some have lakes and trees. Some have meadows covered with flowers. Others have beautiful rock formations. A **rock** is a solid that is a mixture of different minerals.

Grouping Rocks

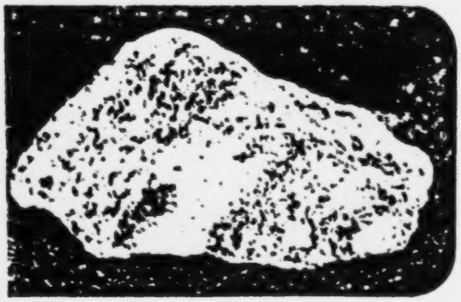
Geologists study and compare rocks. They divide rocks into three main groups. They group them by the way they form. One group forms from melted rock matter. Rocks in the second group form from sediments. The third group is made of rocks that have been changed by heat and pressure. How do you think the rocks in the picture were formed?

Topic 1/Activity 1
Teaching Aid 4, Cont.

Igneous Rock

Hot liquid rock is found deep in the Earth's crust. It is called magma. Sometimes magma cools slowly deep in the crust. Other times it flows out onto the surface. The hot liquid rock that flows onto the Earth's surface is called lava. **Igneous** (IHG nee us) **rocks** are formed from cooled lava.

Magma deep under the surface cools very slowly. Because it cools slowly, large crystals can grow. Magma that cools inside the Earth forms **intrusive** (ihn TREW sihv) igneous rock.

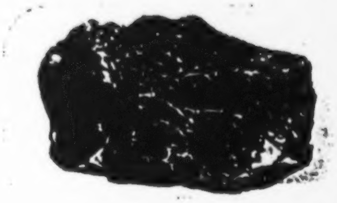


Granite is an intrusive igneous rock. It is used in buildings and monuments. Why do you think granite is used in buildings? How many different colors do you see in the granite shown here? How many minerals are in the granite? How do you know how many there are?

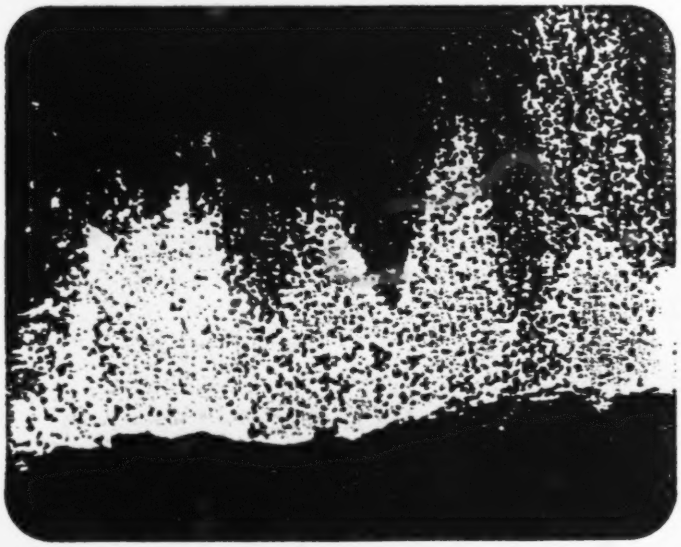
Topic 1/Activity 1
Teaching Aid 4, Cont.

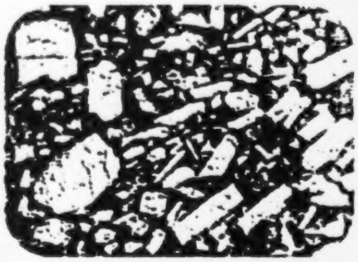
Rocks that form on the surface are called **extrusive** (ihk STREW sihv) igneous rocks. Lava cools faster on the surface. It cools so quickly there is not enough time for crystals to grow large. Some extrusive rocks cool too quickly for any crystals to grow. Study the words "intrusive" and "extrusive." Which parts of the words can help you remember what they mean?

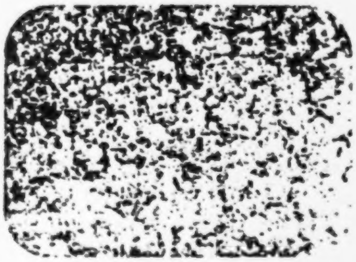
Obsidian (ub SIHD ee un) is an extrusive rock. It forms from very quick-cooling lava. It looks like black glass. Obsidian is used for jewelry and art. Some arrowheads were made from it.



Study the pictures of rocks. Which of them do you think cooled the slowest? Which do you think cooled the fastest? Which might be intrusive rocks? Which might be extrusive rocks?







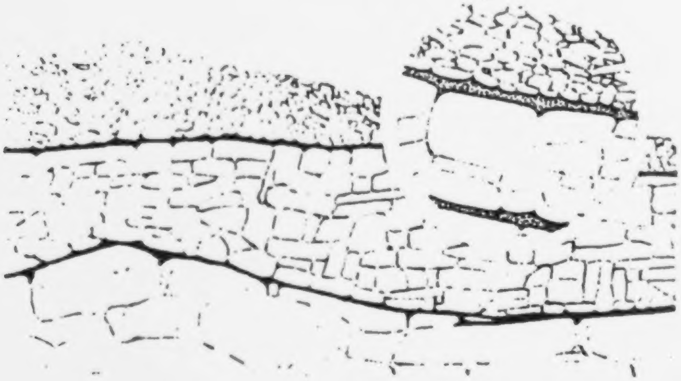
Topic 1/Activity 1
Teaching Aid 4 , Cont.

Sedimentary Rocks

All rocks on the Earth's surface are slowly broken down into small pieces. The rock pieces are called sediments. Sediments can be as large as gravel or as fine as powder.

Sediments are often moved far from where they form. They can be moved by running water, wind, waves, and gravity. They collect in layers at the bottoms of lakes and oceans. Layers of sediment become cemented together to form **sedimentary** (sed uh MENT uh ree) **rock.**

One layer becomes buried under other layers. The layers may be heavy. The weight squeezes the layers of sediment. Sometimes minerals dissolved in water cement the sediments together. Pressure and cementing changes sediments to sedimentary rock. How does the word "sedimentary" help you remember how these rocks were formed?



Topic 1/Activity 1
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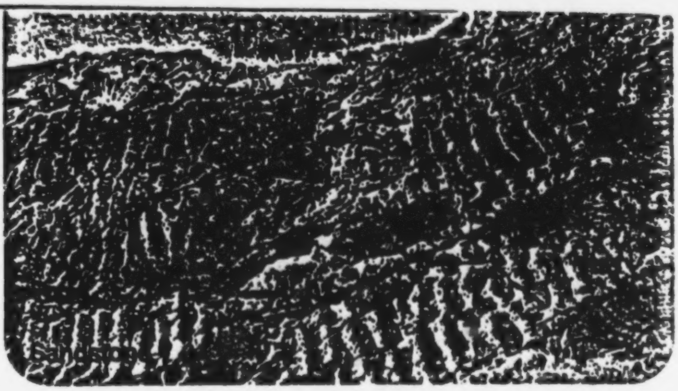
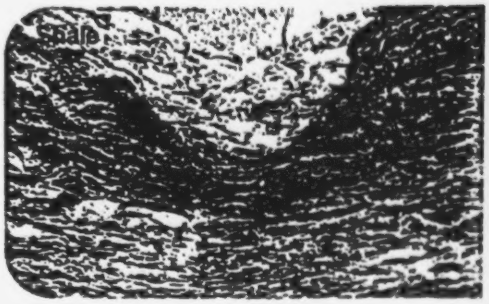
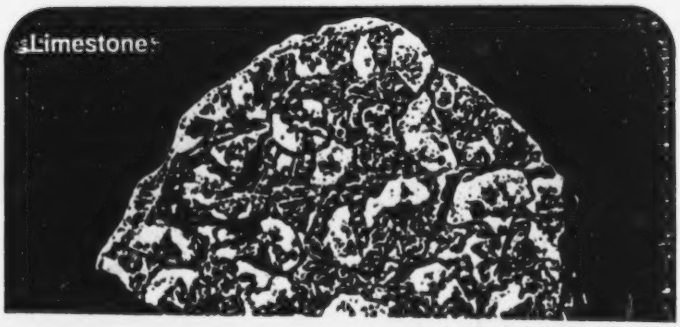


There are different kinds of sedimentary rocks. Large deposits of sand may become sandstone. It feels gritty. The sand grains are easy to see. Where is sand deposited? How might these deposits become sandstone?

Slow moving water can carry very small pieces of sediment. Rivers flowing into lakes and oceans carry fine particles of mud and clay. Mud and clay collect in layers under water. They form a sedimentary rock called shale. Where could you find shale?

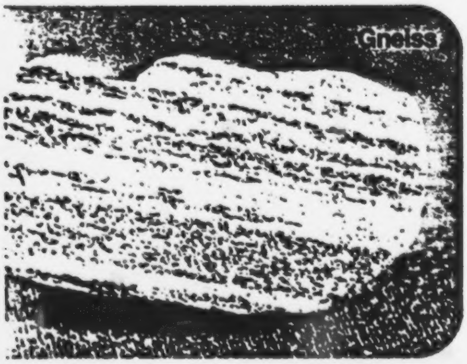


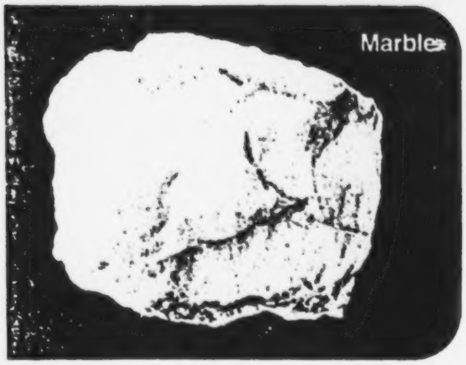
Animal bones and shells contain a mineral. This mineral and the animals are most often found in shallow ocean water. The mineral and animal bones combine to form rock called limestone. Limestone is found in Ohio and Kentucky. Scientists think there once was an ocean covering parts of these states. Why do they think these states were covered by an ocean?



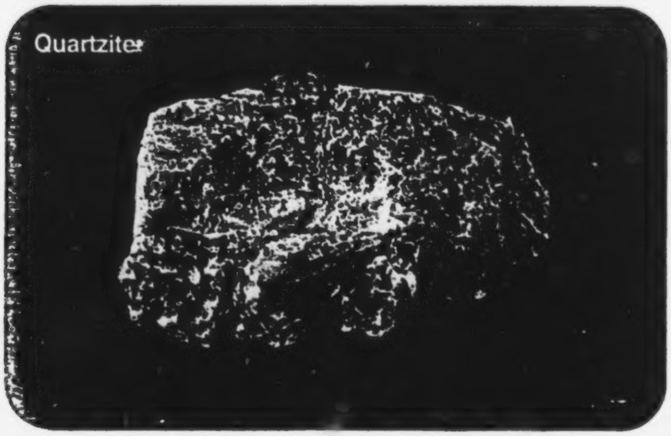
Metamorphic Rock

Metamorphic (met uh MOR fihk) **rock** is formed by heat and pressure. Both igneous and sedimentary rock can be changed to metamorphic rock. Heat and pressure can change shale into a metamorphic rock called slate. Heat and pressure can change granite into gneiss (NISE), limestone into marble, and sandstone into quartzite (KWORT site). What are some uses for metamorphic rock?





Metamorphic rocks can be put in two groups. The groups are banded and nonbanded. Gneiss and slate are banded. Gneiss has bands that are easy to see. You would need a microscope to see the bands in slate. Two of the pictures show nonbanded rocks. What do you think nonbanded means? Marble and quartzite are nonbanded metamorphic rocks. How are they different from banded metamorphic rocks?



OBSERVATION GUIDE II

Once you have decided whether you think your rock is sedimentary, igneous, or metamorphic, use the following questions to help you further observe its characteristics. Make notes about the answer to each pertinent question.

If you think you have a sedimentary rock, use these quesions:

Are the grains large or small as compared to the grains in a piece of chalk?

Were the sediments deposited near the mouth of a river or farther out to sea?

Are the sediments of sand, lime, or clay? (A drop of dilute hydrochloric acid dropped on lime will cause it to effervesce. If a rock formed of clayey material is wetted, it will usually have a slight smell of mud.)

Are there layers in the rock? If so, are the layers of equal width? Are they composed of the same materials?

Are there fossils in the rock? If so, what kind of living thing might have formed the fossil?

If you think you have an igneous rock, use these questions:

Does the rock contain crystals?

If it has crystals, are they comparatively large or small?

Are all the crystals composed of the same materials?

Were the rock crystals formed quickly or slowly?

Were all the rocks in the place where this rock was found of a similar nature?

Was there any evidence to indicate whether some of the rocks were younger than the other rocks?

If you think you have a metamorphic rock, use these questions:

Are there traces of layers in the rock? If so, how have they been changed?

Are there traces of grains in the rock? If so, how have they been changed?

Are there evidences of fossils that may have been changed almost beyond recognition?

ACTIVITY 2: HOW CHILDREN LEARN SCIENCE

In this section, participants will receive information on the psychological and philosophical basis for emphasizing a hands-on, process-oriented approach to teaching science. The leader will present information based on studies by Piaget and others and implications of these studies for classroom practice. The leader will overview research on human brain functioning and will present results of empirical research on hands-on, process-oriented science programs.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Present information on children's developmental stages and the implications of these stages for science teachers.

2. Ask participants to suggest examples of developmentally-appropriate science activities for elementary children.

3. Overview research on brain functioning and implications for teaching science.

4. Present results of empirical research on hands-on, process-oriented science programs.

MATERIALS LIST

Transparencies of Teaching Aids 1-16
Overhead projector
Videotape 1
Videotape player
1 copy of Teaching Aid 17 for each participant
2 strong magnets
Iron filings
1 blank transparency

ADVANCE PREPARATION

Study the teaching sequence and videotapes. Reproduce a handout for each participant.

TEACHING SEQUENCE

1. Present the following materials to participants in lecture format.

Piaget's Work on Children's Developmental Stages and Implications for Teaching Science.

To teach children effectively, adults must know about and appreciate the way they think about things and their typical levels of understanding. Especially pertinent to science education is the work of the well-known Swiss psychologist, Jean Piaget. Piaget and his many followers who have replicated and extended his work outline four stages of intellectual development. They also describe important factors that promote learning.

Educators know that high expectations enhance most students' learning. However, expectations for students must be developmentally appropriate. Let's look at some material on developmental levels to try to get an overview of children's patterns of growth in some areas pertinent to science education.

Most elementary children are in Piaget's preoperational or concrete operational stages. These stages follow the sensory motor stage. In the sensory motor stage (Teaching Aid 1, transparency), children learn to focus on and manipulate objects. They repeat actions and achieve object permanence.

In the preoperational stage (Teaching Aid 2, transparency), children begin to use language and other symbols. The preoperational stage is a period of rapid vocabulary growth. Children learn words from conditioning and as the result of experience. They learn to draw and interpret pictures. By kindergarten and first grade, children can draw representationally in a rudimentary way. They begin to write letters, words, and numerals. All these symbols, along with spoken words, add to preoperational children's communication abilities.

Actual experiences with science materials are essential to children's language development. As children handle, act on, and talk about materials, language becomes meaningful. Children remember what they can understand and begin to relate experiences to other experiences. With meaningful language learning, a disposition for learning and exploring is built in children.

Because of their language and perceptual abilities, preoperational children can observe and describe properties of objects. They usually concentrate or "Center" on one characteristic of an object such as color, and have trouble taking into account other factors. Preoperational children have not developed understanding of the concept of conservation. This means that they do not understand that the number of objects can be rearranged and still have the same number.

Similarly, preoperational children may be shown two identical balls of clay and agree that they contain the same amount of materials. Yet, when one ball is flattened, the child might say there is more clay in the ball because the "pancake" is thinner. The child does not consider that, though the pancake is thinner, it is also wider or that no clay was added or taken away. If one clay ball is formed into a "hotdog," the child might say the hotdog contains more clay than the ball because it is longer. Preoperational children cannot mentally reverse their thinking to "see" that the pancake or hotdog could be reformed into the original ball. (Show segment 1 of videotape 1 to illustrate the Piagetian concepts.)

Preoperational children are beginning to be able to arrange objects in order according to their characteristics. For instance, they could arrange potted plants in order from tallest to shortest or order leaves from darkest to lightest. The number of objects with which they can work, however, is limited. Preoperational children typically have trouble inserting new objects into a series. When they work with ordering, they must compare objects side by side; they cannot order a whole group without making several direct comparisons.

Young children can make simple classifications, but find multiple classifications difficult. Their understanding of space is restricted to that of the immediate environment. Children are just beginning to understand time concepts such as before and after; their understanding of hours, days, seasons, and years is very limited.

Science experience for kindergarteners and first graders, then, must be firsthand and must involve experiences with many objects. To develop young children's language, they must be surrounded with meaningful spoken and written words, and must have numerous opportunities to use language.

Six or seven year olds typically enter the stage Piaget described as Concrete Operational (Teaching Aid 3, transparency). Development through this stage usually continues through age 11 or 12. Children in this stage develop abilities to think logically, but only through concrete means.

For example, suppose we had no experiences in handling magnets and were told facts about a magnetic field. You hear that a magnetic field surrounds a magnet. This field can act like a magnet. When iron filings are sprinkled around a magnet, the filings arrange themselves into a pattern of lines. These lines are called lines of force and they show where the magnetic field is located and how it is arranged. More lines of force are found near the poles of the magnet, where the magnetic force is the strongest, than at the non-pole areas of the magnet. Is all this language clear? Would it be if you were a ten-year old with little previous experience with magnets? Probably not! What would clarify the stated facts for a youngster? Concrete experiences with various magnets are essential if understanding of concepts such as magnetic attraction or magnetic fields is to be realized. (Demonstrate by sprinkling iron filings around a magnet placed on an overhead projector.)

With many experiences, concrete operational children develop ideas of conservation of number, matter, length, area, weight, and volume (back to Teaching Aid 3, transparency). They are therefore ready for concrete and carefully sequenced experiences with measurement.

Measurement concepts and skills are presented in children's math classes and should be utilized in science experiences.

Concrete operational children are able to classify objects and pictures of objects with which they are familiar. To enhance their growing flexibility in thinking, they can be given objects to classify many different ways. Concrete operational children can devise their own classification schemes, as well as work with those suggested by others. They can deal with various subclassifications.

Children's mathematics abilities are growing rapidly, and the children can use their math skills in science situations. They can perform arithmetic operations, tell time on a clock, and understand longer time periods such as days, weeks, months, or years.

Concrete operational children's thinking is becoming more and more sophisticated. They can understand simple causal relationships; discriminate between solids, liquids, and gases; visualize relative positions of objects as seen from the point of view of another person, and use concrete models explaining scientific phenomena. Their growing skills in using art materials and measuring tools let them develop construction projects independently. Concrete operational children's notions of variables and prediction let them understand and devise simple controlled experiments.

Because they are increasingly familiar with symbols--written words, graphs, and numbers--concrete operational children can keep records of observations and experiments. They can learn to interpret diagrams, especially when the diagrams are of familiar objects.

Most middle grades students have not yet achieved Piaget's final stage of formal operations (Teaching Aid 4, transparency). Indeed, Piaget believed that most adults seldom think completely on the formal or abstract level. When faced with new or difficult situations, most adults think better on a more concrete level. Piaget described formal operational people as being able to think in abstract terms--beyond one's own personal experiences. Formal operational people can consider all possible combinations of factors in an experiment. They enjoy thinking about hypothetical situations and can relate one abstraction to another.

To summarize material on concrete operational children, the word concrete should remind educators of the need to work with real materials and to provide a variety of experiences for elementary school children. When teachers present information only in a symbolic, abstract way, many children are lost. Some appear to learn, memorizing facts and "parroting" answers for the short term, but do not retain material for long. With failure to learn, students develop bad attitudes. These negative attitudes can carry over to other school subjects or to school in general. Concrete, hands-on experiences enhance learning and retention.

Piaget's research indicated that five factors are involved in promoting learning (Teaching Aid 5, transparency).

- Physical experience--manipulation of real materials.
- Social experience--interaction with others, confronting the ideas and views of others.
- Logical-mathematical experience--activities involving comparing, grouping, taking apart and putting together, seriating, and counting.
- Equilibration--a mental state of balance in which people take in new information and organize it into both their existing and changing mental schemes.
- Maturation--the passing of time.

Educators can attend to the first four factors with hands-on science experiences for children. Actual experiences let children handle materials and objects. As children work in groups with the teacher's guidance, they have constant social experiences. In laboratory work, children use the logical-mathematical process that Piaget deemed so important. As they problem-solve and experiment, the process of equilibration is enhanced. Hands-on experience is truly suited to Piaget's conception of intellectual development.

Based on Piagetian psychology, Alan J. McCormack devised the following suggestions for science activities for kindergarteners and first graders, most of whom are in the preoperational state (Teaching Aid 6, transparency):

- Have children observe and describe physical changes that take place as time passes. This helps them deal with time and space.
- Invite children to make comparisons of single dimensions of objects (Which is longer, wider, or heavier?). Young children can focus on one aspect of a situation.
- Have children group objects based on a single observable criterion. Here children classify, but concentrate on one aspect.
- Involve children in making observations and descriptions of properties of objects. This develops vocabulary and draws attention to many properties.
- Give children tasks where they can place objects in order based on a single property (length of sticks or size of circles). Young children need practice in seriation.

- Have children observe, and record with drawings, life cycles of common plants and animals. This models recording in a meaningful form.

- Encourage children to pour water into containers of different shapes and sizes, providing readiness for conservation of continuous quantity.

- Involve children in dramatic play using their own bodies to simulate scientific processes (life cycle of a butterfly, growth of a seed). Children transform information which they have seen and heard into another meaningful form.

For second and third graders, in the early concrete operational stage,McCormack suggests (Teaching Aid 7, transparency):

- Have children observe and record variation in a single property within a group of like objects. Children are becoming more sophisticated in their abilities to observe.

- Have children become familiar with sources of sound and the notion that sounds are vibrations. Children explore a concept in a concrete way.

- Encourage students to measure length and weight of objects. Students are ready for hands-on experience with measuring tools.

- Involve children in simple operational tasks (adding, subtracting, ordering) using objects collected from their local environments. Let children use their growing math and thinking skills.

- Encourage invention of imaginary creatures, places, and stories. They both promote creativity and sharpen the difference between fantasy and reality.

- Have children predict changes that may take place, with time, in observed objects or systems of objects. Check out the predictions.

- Have youngsters manipulate and transform objects as frequently as possible (mold a piece of clay into various shapes, bend wire, pulverize sugar cubes) and compare beginning with end states of transformed objects. This promotes understanding of physical changes and is meaningful because it is based on direct experience.

- Have children build structures from drinking straws and Plasticene clay to promote their understanding of spatial relationships and balance.

- Do activities requiring visualization of objects from different points of view. This sharpens spatial understanding, but must be based on real objects, not just pictures.

- Encourage children to offer several reasonable hypotheses when presented with a problem related to concrete objects. They should then decide how to test the hypotheses and actually conduct the tests.

- Involve students in constructing simple scientific apparatus. Students have the physical skills to devise much useful equipment.

- Encourage speculation about the past and future of observed objects. Here students use their inferring and hypothesizing skills.

Robert Karplus and his colleagues also offer more suggestions to encourage intellectual development in middle grade youngsters (Teaching Aid 9, transparency):

- Begin class discussions with discrepant demonstrations, challenges, or puzzles that cause appropriate disequilibrium. Let the children investigate the situations you have introduced. (Show the third segment of the videotape to illustrate older children's interest in an unusual event.)

- Provide time for extensive and repeated experiences with objects. Students need time to resolve contradictions and to become familiar with their own reasoning.

- Encourage discussion among students regarding the investigations they have conducted and data gathered. Encourage students to propose alternative ways of describing or explaining observed relationships.

- Model the reasoning patterns you wish to develop. Reason out loud, and take time to work step-by-step through logical explanations.

Bruner's Work

American psychologist Jerome Bruner complemented Piaget's work by stressing the role of discovery inherent in hands-on science. Bruner suggested that allowing learners to discover information and to organize this information were necessary conditions for learning the techniques of problem solving. He advocated that, wherever possible, children should be given the opportunity to discover concepts for themselves. Bruner discussed four advantages to learning by discovery (Teaching Aid 10, transparency):

- Discovery learning helps children learn how to learn. It builds inquiry and problem solving skills that are applicable to new situations.
- Discovery learning is self-rewarding. It shifts motives away from learning for the sake of satisfying someone else to learning which produces self-satisfaction and pride.
- Discovery learning builds decision-making and problem-solving skills.
- Discovery learning results in knowledge that is more easily remembered and recalled than rote learning.

Bruner described three modes of presentation: His action (or enactive) mode concerns actual contact with real objects. This mode or presentation is most appropriate for preoperational and concrete operational children. It also is a useful mode for formal operational learners who are encountering new concepts for which they have little background. Bruner's imagery (or ikonic) mode concerns the uses of models, pictures, and diagrams as representations for objects. This mode helps learners who are making the transition from concrete to formal operations, but is not as effective for children in earlier stages. Finally, Bruner's language (or symbolic) mode, appropriate for formal operational learners, relies on words and other symbols alone to convey meaning. Experiences involving the use of the action and imagery modes are necessary prerequisites for the language mode.

Gagne's Work

The work of another American psychologist, Robert Gagne, is also pertinent to planning science activities for elementary students. Gagne believed that elementary school science should be taught and learned as a process of inquiry (Teaching Aid 11, Transparency). Children should have many opportunities to generate ideas and hypotheses and to test these in laboratory situations in the classroom. Gagne advocated teaching skills such as observing, describing, classifying, measuring, and inferring as crucial to problem solving. Such skills are important because they are used throughout a person's lifetime.

Suggestions from Other Science Educators

Other science educators recommend classroom applications based on ideas of Piaget, Bruner and Gagne. Some suggestions are (Teaching Aid 12, transparency):

- Stress intellectual development of students rather than accumulation of information. In other words, take a process rather than content-oriented approach. This is in keeping with the new Mississippi State Curriculum Guide.
- Adapt science experiences to the child's developmental level.

Otherwise, learning will be only by rote, or will not occur at all. Avoid forcing reasoning patterns on children that are too far advanced from their present intellectual stage of development.

- Emphasize learning through activity and inductive reasoning patterns. This employs the discovery approach.

- Stress verbal interaction among students in which they compare their thinking related to science problems. "Many heads are better than one." Social interaction among students also decreases egocentricity.

- Talk less and listen more. Provide adequate time for children to think about and respond to questions. Most topics worth thinking about cannot be responded to instantly.

2. Ask participants to work in groups of four. Each group should choose an age or grade level of children and suggest a science activity that, based on the preceding information, is developmentally appropriate for the children. They should present their suggestions to the total group, giving several reasons why they consider their suggested activity to be developmentally appropriate.

3. Continue by presenting the following material in lecture format.

Current Brain Research

Recent knowledge of the way the brain functions has implications for science teaching. We know that the two hemispheres of the forebrain or cerebral cortex are not identical in their functions and capabilities. In about 90% of right-handed persons, the left hemisphere is the center of language, analytical, logical, and sequential thinking. In these same persons, the right hemisphere is generally dominant in visual-spatial, nonverbal, and synthetic reasoning tasks. Cerebral organization is different for 10% of right-handed persons and for about 40% of left-handed individuals. (Teaching Aid 13, transparency)

The right and left hemispheres of the brain let people think in two different but complementary ways. Research tells us that people appear to be able to establish new neuron connections between portions of the brain to establish new linkages in the thinking process. Many researchers believe that the most effective and creative learning occurs when both hemispheres of the brain work together.

The midbrain and limbic systems (Teaching Aid 14, transparency) seem to play a major role in monitoring and controlling people's emotions and interests. The limbic system appears to be connected more to the right hemisphere than the left. This suggests that the right hemisphere is more geared for dealing with and associating emotions and higher levels of thinking. Information is more likely to be remembered if it is associated with some type of strong emotion. If memory of an idea or event is painful, the brain may actually guard against its recall. "Scienceaphobia" or test anxiety may be the result of negative experiences.

The hindbrain and reticular formation (Teaching Aid 15, transparency), lower portions of the brain, filter most sensory input. This area acts as an on/off switch for the whole brain. It appears that the reticular formation is responsible for determining which data the brain will pay attention to and allow to pass to the limbic system and the cerebrum. Data and events that the lower portions of the brain perceive as novel, unexpected, and discrepant seem to work well in "turning on" the brain.

Based on currently available research about human brain functioning, Frederick Staley suggests that the brain is very complex and that no two individuals learn in exactly the same way. Staley draws several implications for schooling. Though Staley made suggestions for science education, his suggestions also apply to other school subjects (Teaching Aid 16, transparency).

- The most effective learning in terms of length of retention and recall is that which engages the learner in multisensory hands-on experiences with real objects.
- Because of a wide range of individual differences, it is probably fruitless to spend much time and energy trying to figure out different children's learning styles. It might be better, when teaching the concepts or topics, to offer a wide range of avenues for students to become engaged in and express their learning. This way children will be able to find activities suitable to their learning styles.
- Interesting, pleasurable experiences must be offered to engage students in learning. Repetitive tasks, work sheets, and drill and practice exercises may disengage the reticular formation and limbic system from the learning process.
- Sensory exploration and manipulation of objects must be accompanied by oral language. Children need to talk, demonstrate, and interact. When children talk about what they are doing, concept and language development are enhanced.
- Children need opportunities for engagement in a variety of modes of interactions with objects and other people. Engagement modes might include listening or reading, sensory explorations, experiments, demonstrations, brainstorming, discussion, drama, nature walks, and simulations.
- Children must have opportunities to express the results of their engagements. Expressive modes might include talking,

reporting, making models, drawing, or designing and conducting experiments on their own.

4. Other Research Findings on Hands-On Science with Elementary Children

Researchers have studied aspects of inquiry-based, laboratory-based, and hands-on sciences and have found many positive results. Educators have also polled teachers to find out about their concerns in science teaching. Some results are summarized on the handout sheet. (Pass out copies of Teaching Aid 17 and discuss it with the participants. Solicit suggestions for conveying research-based information to administrators, other teachers, and parents.)

Piaget's

SENSORIMOTOR STAGE

(Ages birth - two years)

Focus on, move toward objects

Manipulation of objects

Repetition of actions

Object permanence

Topic 1/Activity 2

Teaching Aid 1

(Transparency)

Piaget's

PREOPERATIONAL STAGE

(Ages two - seven)

Vocabulary growth

Work with pictures and symbols

Drawing

Observe and describe objects

Center on one characteristic

Lack of conservation

Ordering

Simple classification

Developing concepts of time, space

Topic 1/Activity 2
Teaching Aid 2
(Transparency)

PIAGET'S THIRD STAGE...

CONCRETE OPERATIONAL

(Ages 6 or 7 - 11 or 12)

Logical thinking through concrete means

Conservation of number, matter, length, area, weight, volume

Classify and subclassify objects

More sophisticated ideas of time

Development of causal relationships

Discriminate solids, liquids, gases

Work with relative positions of objects

Use concrete models

Develop construction projects

Work with simple experiments

Keep records and graphs

Topic 1/Activity 2
Teaching Aid 3
(Transparency)

Piaget's

FORMAL OPERATIONAL STAGE

(Ages 11 or 12 up)

Think in abstract terms

Understand beyond own experience

Consider systematically all factors of a situation

Relate abstractions

Think of hypothetical situations

4 kinds of seeds,
3 kinds of soil...
12 samples for
comparison

Topic 1/Activity 2
Teaching Aid 4
(Transparency)

Piaget's Idea of

FACTORS THAT PROMOTE LEARNING

Physical Experience

Social Experience

Logical - Mathematical Experience

Equilibration

Maturation

Topic 1/Activity 2
Teaching Aid 5
(Transparency)

Mc Cormack's Suggestions

(Preoperational Stage)

GRADES K-1

Observe and describe changes over time

Make comparisons on one factor

Classify and group objects on single criteria

Order objects based on one criteria

Observe plants and animals, record with drawings

Pour water

Use dramatic play to simulate science processes

Topic 1/Activity 2
Teaching Aid 6
(Transparency)

Mc Cormack's Suggestions

(Concrete Operational)

GRADES 4-6

Use simple experiments -- "fair tests"

Require visualization of objects from different points of view

Make and test hypotheses

Construct simple apparatus

Speculate about the past and future of observed objects

Topic 1/Activity 2
Teaching Aid 8
(Transparency)

Karplus' Suggestions

(Concrete Operational)

GRADES 4-6

Use discrepant events

Use extensive and repeated experiences with objects

Encourage discussion of data and results

Model logical thinking

Topic 1/Activity 2
Teaching Aid 9
(Transparency)

BRUNER

Advantages of LEARNING BY DISCOVERY

Helps learn how to learn:

inquiry skills

problem solving

Self-rewarding; intrinsic rewards

Builds decision-making abilities

Knowledge is easily remembered and retained

Modes of presentation

1. action
2. imagery
3. language

Topic 1/Activity 2
Teaching Aid 10
(Transparency)

GAGNE'

SCIENCE AS INQUIRY

Generate ideas and hypotheses; test them in lab

Skills for problem solving:

observing
describing
classifying
measuring
inferring

Skills used throughout lifetime

Topic 1/Activity 2
Teaching Aid 11
(Transparency)

Classroom
IMPLICATIONS

based on works of Piaget, Bruner, Gagne'

Stress intellectual growth -- process not content

Adapt activities to developmental stages

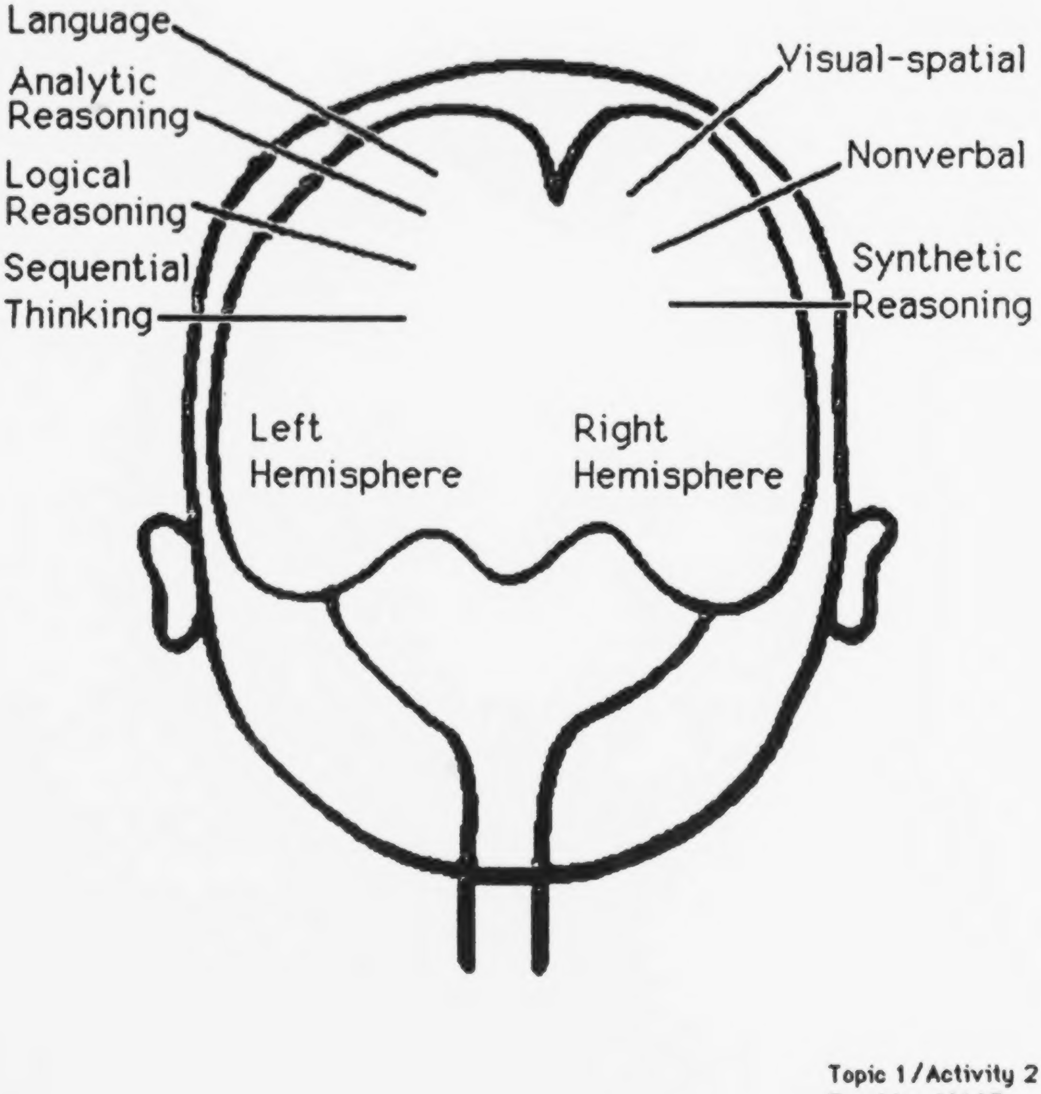
Emphasize learning through doing and discovering

Stress verbalizations and interactions among students

Topic 1/Activity 2
Teaching Aid 12
(Transparency)

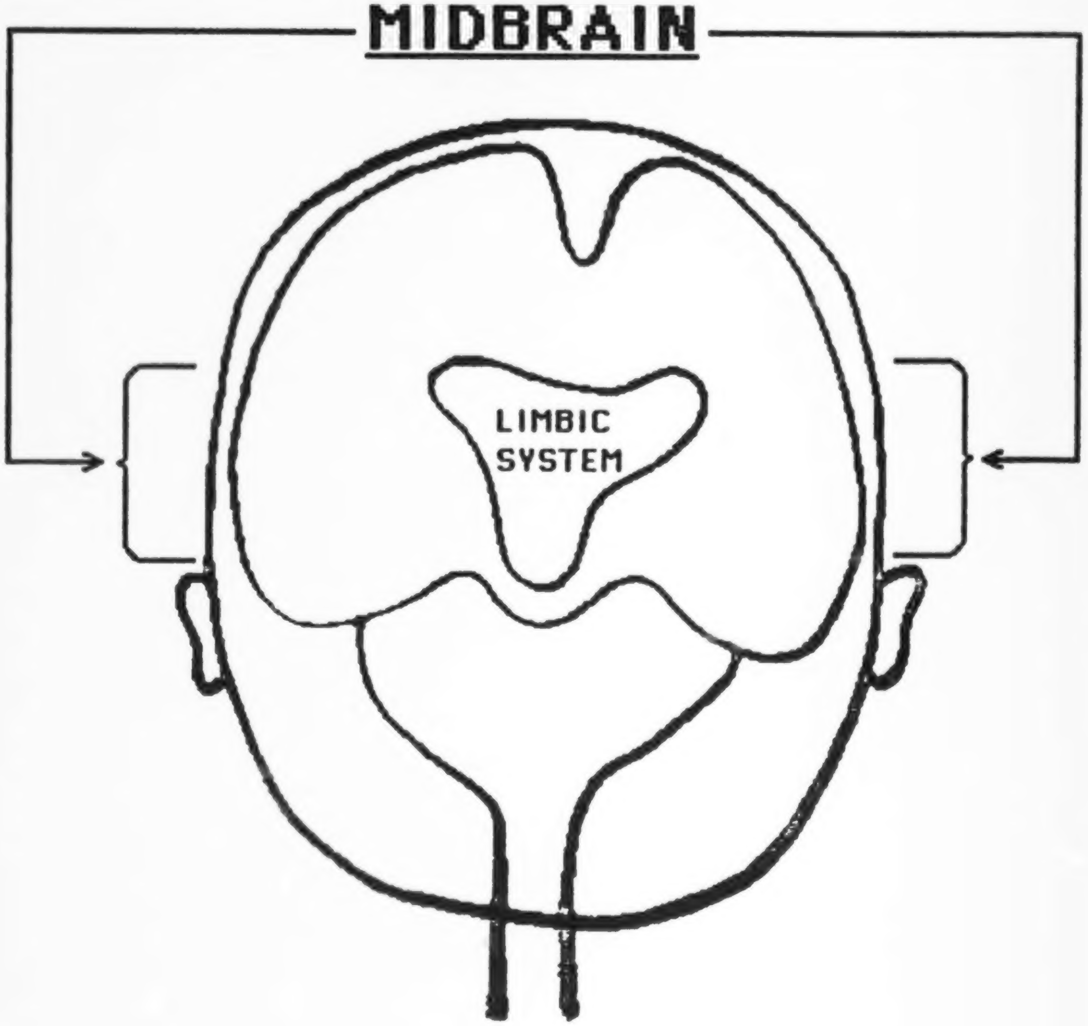
HUMAN BRAIN ORGANIZATION

FOREBRAIN


Language
Analytic Reasoning
Logical Reasoning
Sequential Thinking
Visual-spatial
Nonverbal
Synthetic Reasoning
Left Hemisphere
Right Hemisphere

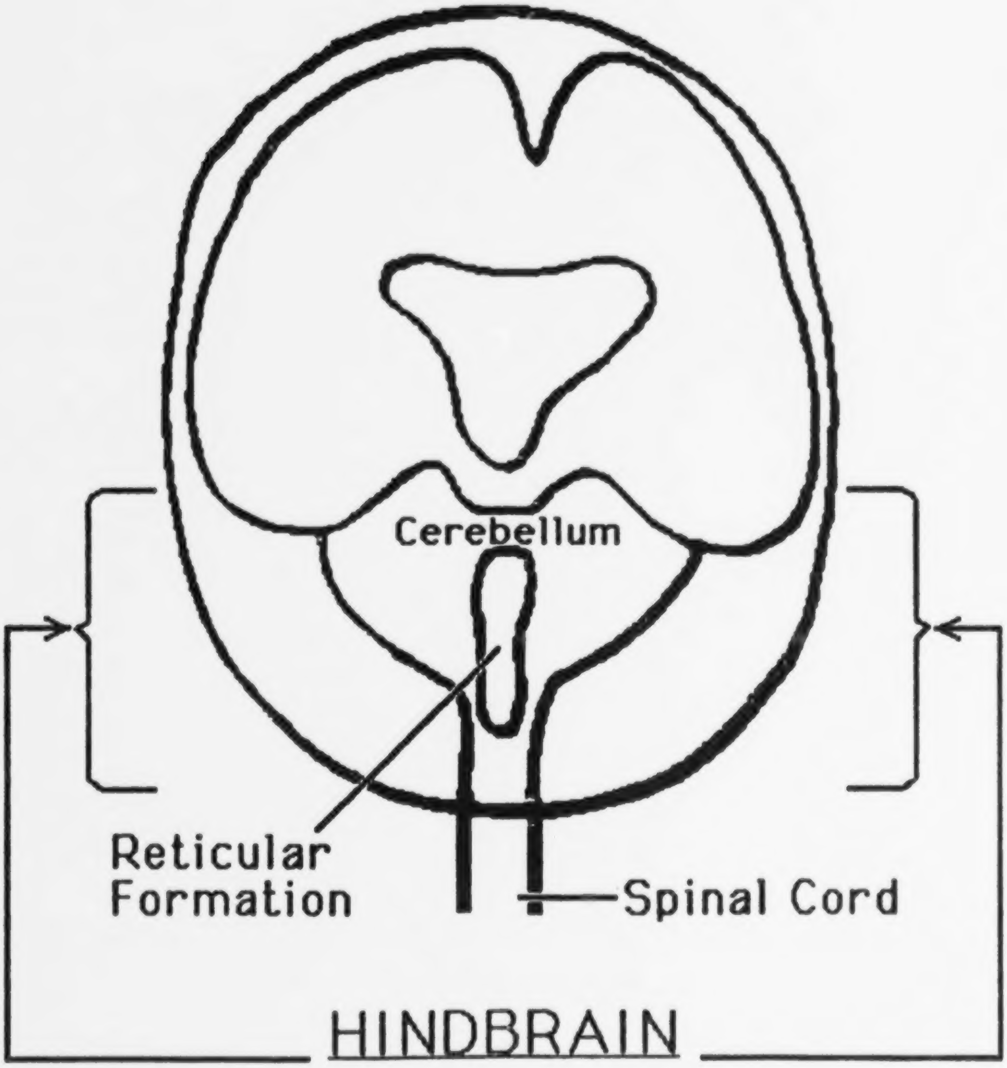
Topic 1 / Activity 2
Teaching Aid 13
(Transparency)

HUMAN BRAIN ORGANIZATION


MIDBRAIN
LIMBIC SYSTEM

Topic 1 / Activity 2
Teaching Aid 14
(Transparency)

HUMAN BRAIN ORGANIZATION


Cerebellum
Reticular Formation
Spinal Cord
HINDBRAIN

Topic 1 / Activity 2
Teaching Aid 15
(Transparency)

BRAIN RESEARCH

Staley's Implications

Multisensory, hands-on experiences most effective

Range of avenues for engagement and expression will accommodate learning styles

Pleasurable, interesting experiences

Oral language to accompany exploration and manipulation

Variety of engagement and expressional activities

Topic 1/Activity 2
Teaching Aid 16
(Transparency)

RESEARCH FINDINGS

HANDS-ON SCIENCE

Some recent results of research on inquiry-based, laboratory-based, and hands-on science are summarized below:

Situation	Effect
Students have few opportunities to manipulate materials in science classes.	Students see science as dull, "No fun," and a place where they do not want to be.
Students have opportunities to handle, operate, and work with physical objects; students use concrete materials.	More science achievement gains than when students are involved in reading about the objects or watch someone else work with the materials.
Students participate in inquiry-oriented science activities.	Achievement in science is heightened; students also perform better in language arts, math, social studies skills, and communication skills.
Students are involved in hands-on science activities.	Students gain confidence in their abilities to learn science and like science more.
Teachers use set induction and advance organizers to focus attention on the lesson; teachers provide connections between new and previous learning.	Students are better prepared to learn subsequent material.
Students engage in inquiry-oriented, hands-on science curricula developed during the 1960's and early 1970's.	Students have enhanced attitudes toward science and scientists. Students have enhanced higher level thinking skills, critical and analytic thinking skills, problem-solving abilities, creativity, and process skills. Students better understand and retain science concepts.
Students are involved in sciencing, rather than talking about it.	Student attitudes toward science, and toward school in general, improve.
Teachers from 98 schools interested in good science instruction are polled concerning their interests in science education.	85% of the teachers ranked hands-on experiences as the most interesting topic from a list of 28 items.

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Jacobsen, Willard and Abby Bergman. Science for Children. Englewood Cliffs, NJ: Prentice-Hall, 1980.

Rowe, M. B. (ed.). What Research Says to the Science Teacher, Volumes 1 and 2. Washington, DC: National Science Teachers Association, 1978, 1979.

Victor, Edward. Science for the Elementary School. New York, Macmillan, 1985.

"What Research Says" columns from Science and Children magazine, edited by Mary Budd Rowe, provide up-to-date research on selected topics in science for the elementary school. We used "Six Strategies for Improving Attitudes Toward Science" by T. R. Koballa and D. R. Rice (Volume 22, no. 6, pp. 32-34, March 1985) and "What's Your Choice?" by D. Gabel (Volume 23, no. 4, pp. 129-131, January 1986) as references for some of the material in this handout.

TOPIC 2: EXPLORING THE BASIC SCIENCE PROCESSES

Jean Shaw
University of Mississippi

This session introduces the basic science processes of measuring, communicating, predicting, inferring, and using time and space relationships. Participants will also use the basic processes of observing and classifying that were previously introduced. Working with these processes lets people acquire knowledge. Elementary children need direct involvement if they are to fully understand science content. Using the processes lets learners use the tools of scientific inquiry.

The basic processes are suitable for use by children in kindergarten through the third grade. They also provide a background and framework for the higher level integrated skills older children will use as they design and conduct simple experiments.

In this session, participants will receive information on the basic processes. Then they will work in groups on different activities in which they actively use the processes. The groups will both share their results and the particular ways they used the processes as they worked. The groups will also consider ways to modify their activities for use in various classroom settings.

ACTIVITY 1: INTRODUCING THE BASIC SCIENCE PROCESSES

In this brief segment, the workshop leader will introduce and define the basic science processes. This segment will clarify terms for participants.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Define and give examples of each basic science process (observing, measuring, classifying, communicating, predicting, inferring, and using time and space relationships).

2. Invite participants to give examples of each process.

MATERIALS LIST

Teaching Aids 1-9 (transparencies)
An interesting visual aid, such as a bird nest
1 box paper clips
2 strong magnets
1 balance scale with gram weights

ADVANCE PREPARATION

Prepare the transparencies from Teaching Aids 1-9. Study the teaching sequence. Choose a visual aid.

TEACHING SEQUENCE

Introduce the session and present the basic science processes using statements such as those that follow:

In this session, we will explore and use the basic science processes of observing, measuring, classifying, communicating, predicting, and inferring (Teaching Aid 1, transparency). We started observing and classifying and used some measuring in our last session. Let's look at some definitions of the processes.

OBSERVING is gaining information about objects and events through use of the senses (Teaching Aid 2, transparency). Observing may involve looking--often looking carefully for specific details--but it may also involve listening, touching, and, with caution, smelling, and tasting. A trained observer can identify birds by their songs. Teachers can usually identify particular students by their voices or even by the sounds of their footsteps. Observing by listening is common. We often tell what's cooking by its odor. We can tell much about the texture of objects by touch. We can't see one magnet attract another directly, but if we hold opposite poles of two magnets close together, we can definitely feel their attraction. We can also feel the magnets repel when like poles are held close together. (Illustrate: Pass around the magnets for those who want to feel the forces you have described.) Children need practice using all their senses to find out more about objects and events.

We saw in the last session that observations involved direct, first-hand knowledge. Observations may involve both qualitative and quantitative data. Qualitative data describes qualities or properties of phenomenon. Qualitative data can be referenced. The bird nest is smaller than the desk, but larger than my hand (or give an example with the other visual aids). Quantitative data attaches numbers and measurements to phenomenon. It gives precision to words like long, wide, or heavy. Observations may involve acting on objects to see what happens to them under various conditions. Will the nest fall apart easily? We could act on it and find out. Will the nest survive rain? We might place it outdoors in the rain or simulate a rain storm with water in a shaker bottle to find out.

Can you share some examples of some things you observed as you came to class this morning? (As examples are given, follow up on them asking for the sense(s) used, qualitative or quantitative data, or instances of acting on objects.)

MEASURING is used in quantitative observations (Teaching Aid 3, transparency). Standard or nonstandard measuring devices may be used. We may describe the width of the bird's nest here as about 10 centimeters (use the actual measure). The nest is about 6 centimeters high. If we weigh the nest, we could express its mass in grams, or we might use a nonstandard unit such as paper clips. (Ask a participant to use the balance scale and determine how many paper clips will balance the nest.) As young children measure, teachers must remember that they are building skills and typically use measuring tools with less precision than older children. Children need experiences in using measures of length, temperature, mass, volume and time. What are a few examples of each of these kinds of measures that young children could use in science?

CLASSIFYING (Teaching Aid 4, transparency),as we saw in our last session, is the systematic arrangement of materials into a series of groups and subgroups on the basis of characteristics. Classification systems let people impose order on collections of objects or events. Scientists have worked for years to classify the plant and animal kingdoms. Young children might use very simple classifications for animals such as wild and tame, furry and not furry, or animals that fly versus animals that don't fly. We classify rocks. We classify materials based on physical properties such as color, hardness, solubility, or magnetic attraction. Young children need to start with simple classification schemes and gradually increase the number of subgroups they deal with. Classifying is used by children every day. They classify numbers as to whether they're odd or even, or multiples of five or not. They classify words as nouns or verbs. Can you give some examples of other things that young children might be interested in classifying in science?

COMMUNICATING is a science process that is hard to separate from work with any other process. Communicating (Teaching Aid 5, transparency) is sharing information with others and understanding information received from others. Communication is often verbal. As children and teachers work together, they share ideas and questions in oral form. Communication can also be nonverbal--pointing, gesturing, and facial expressions often communicate as effectively as words do. Other communication forms are graphs, diagrams, pictures, maps, and written symbols. How have we used some of these forms of communication so far in this workshop? What are some other forms of communication children use in science?

In a well-known definition of science, Paul Blackwood commented that "Science is what scientists do" (Teaching Aid 6, transparency). Blackwood further discussed the idea that scientists describe, predict, and explain. Effective descriptions involve processes we have discussed: careful observations, pertinent measurements, and meaningful communications. Scientists also predict (Teaching Aid 7, transparency); they tell in advance what they think will happen in a given situation. Predictions are more than wild guesses of future happenings. Predictions are based on knowledge of the past, on observations, and on measurements. Children grow in their knowledge of science and its processes; they can make increasingly sophisticated predictions. Predictions often generate interest in science activities. They represent a small "investment" of thought and make learners more interested in the outcomes than they would be without making predictions. What are some predictions that either scientists or children make based on prior knowledge or experience?

INFERENCES are also a part of Blackwood's definition of science. Scientists use inferences as they explain or make generalizations about phenomenon (Teaching Aid 8, transparency). Inferences are more than observations--making good inferences involves thought. If a third grader is given a sealed box and asked what might be inside, she might shake the box. If she hears rattles, she might infer that the contents are free to move within the box. If the box is relatively heavy, she might infer that it contains a rock, some fishing sinkers, or a book. If the box is relatively light and doesn't rattle, the child might infer that the box is empty, contains small objects packed in styrofoam, or is full of cotton balls. Inferring is reaching conclusions based on evidence. Inferences are important in science. Although no one has directly examined the core of the earth, scientists make inferences about the nature of the core based on evidence gathered from study of earthquake waves, the mass of the earth, and the earth's magnetic fields. We have not traveled to Uranus to observe the composition of that mysterious planet, but make inferences about its nature from data gathered about its orbit, probable origin, gravitational pull, and photos of its surface. What are some inferences you might make about this bird nest (or other object)? Tell what data or past experience you're basing your inferences on. (Next, invite questions or additional examples from participants.)

USING TIME AND SPACE RELATIONSHIPS is a final basic science process (Teaching Aid 9, transparency). The process involves stating of location, understanding positions and changing positions of moving objects, and dealing with objects and changes over a period of time. As children work with time and space relationships, they must use directional and positional words, such as front, back, right, left, above, below, on, inside, and outside. They describe the locations of objects relative to other objects. They work with changes that occur in longer and shorter periods of time. What are some more examples of children's use of time and space relationships in the science classroom?

BASIC

Science Processes

Observing

Measuring

Classifying

Communicating

Predicting

Inferring

Using Time, Space Relationships

Topic 2/Activity 1
Teaching Aid 1
(Transparency)

OBSERVING

GAINING INFORMATION USING SENSES

DIRECT, FIRST-HAND KNOWLEDGE

QUALITATIVE -- may be referenced

QUANTITATIVE -- uses numbers or measures

MAY INVOLVE ACTING ON OBJECTS

Topic 2/Activity 1
Teaching Aid 2
(Transparency)

MEASURING

STANDARD

OR

NONSTANDARD

May include

length

temperature

mass

volume

time

Topic 2/Activity 1
Teaching Aid 3
(Transparency)

CLASSIFYING

SYSTEMATIC ARRANGEMENT

USES GROUPS AND SUBGROUPS

MAY CLASSIFY ON MANY CHARACTERISTICS

color
hardness
solubility
appearance
size

Topic 2/Activity 1
Teaching Aid 4
(Transparency)

COMMUNICATING

SHARING INFORMATION

RECEIVING INFORMATION

MANY FORMS

verbal
nonverbal
graphs
diagrams
pictures
maps
written words

Topic 2/Activity 1
Teaching Aid 5
(Transparency)

Paul Blackwood:

"Science is what scientists do"

DESCRIBE

PREDICT

EXPLAIN

Topic 2/Activity 1
Teaching Aid 6
(Transparency)

PREDICTING

TELLING IN ADVANCE
WHAT WE THINK WILL HAPPEN

BASED ON KNOWLEDGE OF PAST
OBSERVATIONS
MEASUREMENTS

PREDICTIONS GENERATE INTEREST IN OUTCOMES

Topic 2/Activity 1
Teaching Aid 7
(Transparency)

INFERRING

MAKING GENERALIZATIONS OR CONCLUSIONS BASED ON OBSERVATIONS OR EXPERIMENTS

GRASS GROWN IN CLOSET -- LITTLE LIGHT	GRASS GROWN ON WINDOW SILL AFTERNOON SUNLIGHT

"THE SUNLIGHT MAKES IT GREENER, I GUESS."

"MORE GRASS GREW IN THE SUNLIGHT.
IT LOOKS HEALTHIER.
PLANTS NEED SUN TO GROW."

Topic 2/Activity 1
Teaching Aid 8
(Transparency)

Using

TIME AND SPACE RELATIONSHIPS

Locations

Positions

Changes over time period

Topic 2/Activity 1
Teaching Aid 9
(Transparency)

ACTIVITY 2: USING THE BASIC SCIENCE PROCESSES IN HANDS-ON ACTIVITIES

This portion of the workshop involves groups working on five different activities, analyzing their activities, and sharing results. Each activity involves the participants in many of the basic science processes.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Give instructions for activities and organize five groups of participants to work on them.
2. Supervise and interact as participants follow written directions to conduct activities and discuss classroom applications.
3. Lead a discussion in which participants show and tell about their results.

MATERIALS LIST

For each participant:

1 copy Teaching Aid 1
1 copy Cards 1-5

For group work:

Body Measures I (Card 1)

2 2 m tapes or 4 meter sticks
1 roll masking tape
Lung capacity device (plastic jug, tape, rubber tubing)
Towels
4 oz. antiseptic mouthwash
Watch with second hand
5 sheets plain paper

Candle Jars I (Card 2)

3 jars (approximately 250 ml, 500 ml, 1000 ml)
3 candle stubs (6-10 cm long)
1 roll masking tape
Watch with second hand
30 x 30 cm square aluminum foil
1 pair scissors
5 sheets plain paper

Balloon Race (Card 3)

5 balloons of different sizes and shapes
11 m nylon rope
1 permanent marker
1 meter stick
5 plastic straws
1 roll masking tape
5 sheets paper

Paddle Boats (Card 4)

8 styrofoam trays
8 rubber bands
2 pairs scissors
20 crayons
1 roll masking tape
1 wallpaper soaking tray
1 meter stick
10 sheets plain white paper

Classification I (Card 5)

2 pencils
5 sheets paper
1 roll transparent tape
1 poster board
30 pressed leaves
1 copy Teaching Aid 2
1 30 cm ruler

ADVANCE PREPARATION

Duplicate the handouts and gather materials. You might arrange materials for each group activity in a separate pile. Prepare the lung capacity device from Card 1.

TEACHING SEQUENCE

1. Organize five different groups. Each group should then select a leader, a recorder, and a reporter (to share findings at the end). All group members should perform the main steps of the activity. Distribute Teaching Aid 1 and Cards 1-5 and give participants a few minutes to look over the material to see the nature of the five activities. Ask them not to read the backs of the cards yet. Now let participants select an activity, get their supplies and move to a specified area of the room to work together.

2. Circulate and help with problems and questions as the participants work. If things are going smoothly, simply listen and encourage. If problems occur, help participants solve them.

3. After the work is completed and records of results have been made, lead a discussion in which groups show and tell what they did and address questions 2a-1 on Teaching Aid 1. Help participants evaluate their recording of results by use of the following questions:

    (1) Were graphs or charts entitled so that people could understand them even if they hadn't participated in the activity?

    (2) Were rows, columns, and graph axes labeled?

    (3) Did you use a suitable, uniform scale where applicable?
    (4) Are results legible?
    (5) How else might the data have been shown?

    Invite participants to ask questions or offer additional comments or reactions. Allow time for cleanup. Take a short break.

USING THE BASIC SCIENCE PROCESSES IN ACTIVITIES

Children can use the science processes -- observing, measuring, communicating, classifying, predicting, and inferring -- in simple hands-on activities. They gain knowledge as they work with the activities, but they also develop skills in using the processes. As you work with several activities, you will have an opportunity to use most or all of the basic science processes.

General Directions

1. Choose and carry out one of the activities that are described on Cards 1-5.
2. Work together to analyze the activity and answer the following questions:
    a. What did you observe? What characteristics of observation did you employ as you worked? (Direct observation, use of senses acting on object as appropriate.) What quantitative and qualitative data did you gather?

    b. How did you communicate as you carried out the activity? What different forms of communication did you use (oral or written language, graphs, charts, body language)?

    c. What predictions did you make during the activity?

    d. Did you work with any time and space relationships? What were they?

    e. What inferences did you make? Did any results surprise you?

    f. What content did you learn? What would children learn from the activity? What questions could you use to guide and enhance the students' learning?

    g. Compare your results on questions a-f with the written comments on the back of your activity card. Add other comments and write down your suggested questions for children. Add some ways to extend your activity to the back of the activity card.

    h. What grade level do you think the activity is on? How might you modify the activity to make it simpler or more sophisticated to meet the needs of younger or older children?

    i. What safety factors should be considered in your activity?

    j. You worked in a small group on your activity. How could you modify the activity so that every student in a class of 25 to 30 children could be involved?

   k. How could children be involved in gathering equipment or cleaning up?

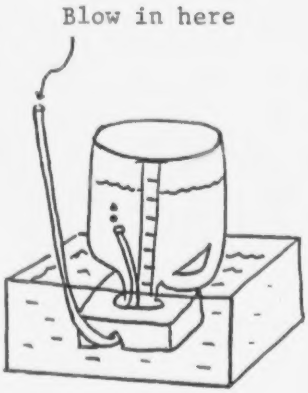
   l. Add other pertinent comments.

3. Plan to report to the other participants briefly showing and describing what was involved in your activity and highlighting answers to the above questions.

4. Clean up your area as much as possible, but save enough equipment and results to make your report to the other participants clear. After the final discussion, finish cleanup and return all equipment to its original place.

Body Measures I

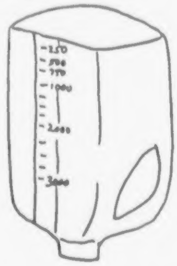
1. Set up a measuring tape or two meter sticks. Determine and record the height of each group member.
2. Record each person's foot length and waist measurement.
3. Predict each person's approximate lung capability. Each person should then blow into the tube exhaling as much breath as possible. The difference in the water level before and after the exhalation is the person's approximate lung capacity.
   Wipe off the tube with antiseptic after each person's turn.
4. Record each person's breath rate per minute. Exercise for two minutes, then record breath rates again.
5. Make some inferences based on the data above.
6. Create some interesting and informative ways to show your data.

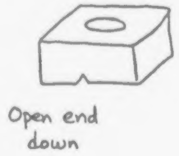


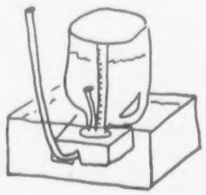
Card 1a

DIRECTIONS FOR MAKING A BREATH METER TO MEASURE APPROXIMATE LUNG CAPACITY

The breath meter measures approximate lung capacity.
It is easy to make from common materials using these instructions:







1. Affix a piece of masking tape to a clean 1 gallon jug. Calibrate the tape in 250 ml intervals. (Pour 250 ml water into the jug, make a mark, pour in 250 ml more, and so.) Turn the jug upside down and write numbers on it.

2. Use sturdy scissors to cut a notch and hole in a small plastic container as shown. A half-pint freezer container works well.
3. Cut 1 m plastic or rubber tubing.
4. To set up the apparatus, fill a tub about 2/3 full of water. Submerge the plastic container. Fill the jug with water. Hold your hand over the top of the jug. Invert the jug and fit it upside down in the container as shown. Thread the tube into the jug.
5. To measure approximate lung capacity, note the water level on the jug. Take a deep breath and exhale into the tube. Exhaled air will displace some of the water. Read the water level. Subtract the starting point from the second reading. The difference is the approximate lung capacity. Cleanse the end of the tube with antiseptic. Refill the jug for the next person.

Body Measures I

Science Processes Used: Measuring, observing, communicating, predicting, inferring, using time and space relationships.

Concepts: People's body measurements vary. Lung capacities vary. Exhaled air bubbles rise in water. Exercise increases breath rates to varying degrees.

Ways to Extend the Activity: Use other body measurements. Figure out other ways to measure approximate lung capacities. Let each person exhale in three trials and find the average. Compare children's and adult's lung capacities.

Suggested Questions for Children:

Card 1b

Candle Jars I

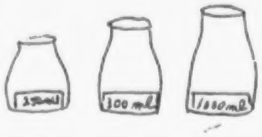
1. Measure the capacity of each of the three jars in milliliters. Mark each jar. Crumple foil to make a stable base for the candle stubs.

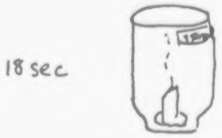
2. What will happen if you light a candle, then place an inverted jar over it? Make some predictions and test them out.

3. Now predict how long a candle will burn under each of the three jars. Test out your predictions.

4. Make some inferences based on your observations and measurements.

5. Show your data in some interesting and informative ways.





Card 2a

Candle Jars I

Science Processes Used: Measuring, observing, communicating, predicting, inferring, using time and space relationships.

Concepts: The jar prevents fresh air (with oxygen) from reaching the candle. As the oxygen in the jar is burned by the candle, the flame goes out. The larger the jar, the more oxygen is available and the longer the candle burns.

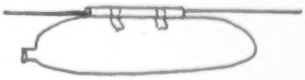
Ways to Extend the Activity: Use other jars. Use other candle lengths.

Suggested Questions for Children:

Card 2b

Balloon Race

1. With the permanent marker, mark the nylon string off in intervals of 1 meter.
2. Inflate a balloon but don't tie it. Attach a straw to the balloon with tape as shown. This will make a carrier for the balloon to be attached to the string. Deflate the balloon.



3. String the straw carrier onto the string, placing the balloon in the middle. Inflate the balloon. Predict which way the balloon will go when it is released. Release the balloon and test your prediction.
4. Now move the balloon to one end of the string, arranging it so it can move forward as much as 10 m. Predict how far it will go. Release the balloon. Count off and record the distance.
5. Will different balloons travel different distances? Use several shapes of balloons and find out. Make and check predictions.
6. Make some inferences.
7. Show your data in some interesting and informative ways.

Card 3a

Balloon Race

Science Processes Used: Measuring, observing, communicating, inferring, time and space relationships.

Concepts: When the balloon is released, the action force of the air rushing out of the balloon results in an equal reaction force in the opposite direction causing the forward motion of the balloon.

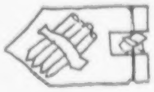
Ways to Extend the Activity: Design other devices that move by air.

Suggested Questions for Children:

Card 3b

Paddle Boats

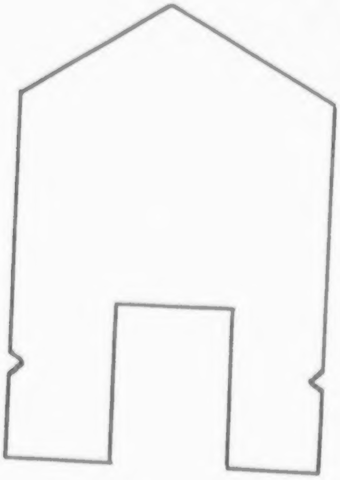
1. Use pattern shown below. Cut paddle boats from styrofoam. Fasten a rubber band to each as shown.
2. Test a boat by winding up the paddle and placing the boat in the middle of the water-filled wallpaper tray. Don't release the paddle yet. Predict what will happen when you release the paddle. Which way will the boat go? Will the boat go forward?
3. Predict how far each boat will travel in the tray. Count the winds on the paddles and measure the distances. Record your data.
4. Attach crayons to each boat with masking tape. Use questions such as: Will a boat with 10 winds on the paddle and 1 crayon go as far as a boat with 10 winds and 4 crayons? Test out some predictions.
5. Make some inferences.
6. Show your data in some interesting and informative ways.



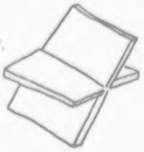
Card 4a

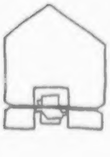
Paddle Boat

Cut the 3 pieces from styrofoam. Make the paddle as shown. Use an 8 cm wide rubber band to fasten the paddle to the boat.



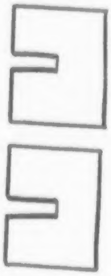
Fit paddle pieces together.





Fasten paddle in place with rubber band.

paddle pieces



Paddle Boats

Science Processes Used: Measuring, observing, communicating, predicting, inferring, using time and space relationships.

Concepts: The boats travel in the same direction as the paddles unwind; if the paddle moves forward or counterclockwise as it unwinds, the boat moves forward. More winds make the boats go further than fewer winds. Boats loaded with crayons require more force (winds) to make them go the same distance as unloaded boats.

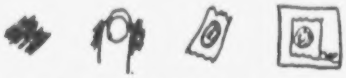
Ways to Extend the Activity: Experiment with different boat designs such as sail boats or differently shaped paddle boats. Experiment with different loads on "land vehicles" such as toy cars.

Suggested Questions for Children:

Card 4b

Classifications I

1. You will do two classification exercises.



2. Each group member should make a fingerprint of the right index finger and the left thumb. Scribble with pencil. Rub a finger in the scribbling; then, print onto the sticky side of transparent tape. Tape the print onto a 5x5 cm square of white paper.
3. Label your fingerprints.
4. Classify the prints at least two different ways. You might want to use information from Teaching Aid 2 to help with one way of classifying.
5. Your second classifying activity involves leaves. Choose at least 20 leaves. Devise a system by which you could make groups and subgroups of the leaves. You might consider the sizes, shapes, edges, colors, or vein patterns of the leaves. Arrange your leaves on the poster board and label your classification system.
6. Did you observe, measure, predict, or infer as you worked? How?

Card 5a

Classification I

Science Processes Used: Observing, measuring (if lengths or widths of leaves are determined as a basis for classifying), classifying, communicating.

Concepts: Individual fingerprints vary in subtle ways. Leaves vary in many ways. Fingerprints and leaves can be classified according to their characteristics.

Ways to Extend the Activity: Let children suggest other materials to classify. Let children suggest other ways to classify fingerprints and leaves.

Suggested Questions for Children:

Card 5b

Introduction*

This booklet concerning the study of fingerprints has been prepared by the Federal Bureau of Investigation for the use of interested law enforcement officers and agencies, particularly those which may be contemplating the inauguration of fingerprint identification files. It is based on many years' experience in fingerprint identification work out of which has developed the largest collection of classified fingerprints in the world. Inasmuch as this publication may serve as a general reference on classification and other phases of fingerprint identification work, the systems utilized in the Identification Division of the Federal Bureau of Investigation are set forth fully. The problem of pattern interpretation, in particular, is discussed in detail.

Criminal identification by means of fingerprints is one of the most potent factors in obtaining the apprehension of fugitives who might otherwise escape arrest and continue their criminal activities indefinitely. This type of identification also makes possible an accurate determination of the number of previous arrests and convictions which, of course, results in the imposition of more equitable sentences by the judiciary, inasmuch as the individual who repeatedly violates the law finds it impossible to pose successfully as a first, or minor, offender. In addition, this system of identification enables the prosecutor to present its case in the light of the offender's previous record. It also provides the probation officers, parole board, and the Governor with definite information upon which to base their judgment in dealing with criminals in their jurisdictions.

From earliest times, fingerprinting, because of its peculiar adaptability to the field, has been associated in the lay mind with criminal identification to the detriment of the other useful phases of the science. However, the Civil File of the Identification Division of the Federal Bureau of Investigation contains three times as many fingerprints as the Criminal File. These civil fingerprints are an invaluable aid in identifying amnesia victims, missing persons, and unknown deceased. In the latter category the victims of major disasters may be quickly and positively identified if their fingerprints are on file, thus providing a humanitarian benefit not usually associated with fingerprint records.

The regular contributors who voluntarily submit fingerprints to the Federal Bureau of Investigation play a most important role in the drama of identification. Their action expands the size of the fingerprint files, thereby increasing the value of the files to all law enforcement agencies. Mutual cooperation and efficiency are resultant by-products.

The use of fingerprints for identification purposes is based upon distinctive ridge outlines which appear on the bulbs on the inside of the end joints of the fingers and thumbs. These ridges have definite contours and appear in several general pattern types, each with general and specific variations of the pattern, dependent on the shape and relationship of the ridges. The outlines of the ridges appear most clearly when inked impressions are taken upon paper, so that the ridges are black against a white background. This result is achieved by the ink adhering to the friction ridges. Impressions may be made with blood, dirt, grease or any other foreign matter present on the ridges, or the saline substance emitted by the glands through the ducts or pores which constitute their outlets. The background or medium may be paper, glass, porcelain, wood, cloth, wax, putty, silverware, or any smooth, nonporous material.

Of all the methods of identification, fingerprinting alone has proved to be both infallible and feasible. Its superiority over the older methods, such as branding, tattooing, distinctive clothing, photography, and body measurements (Bertillon system), has been demonstrated time after time. While many cases of mistaken identification have occurred through the use of these older systems, to date the fingerprints of no two individuals have been found to be identical.

The background and history of the science of fingerprints constitute an eloquent drama of human lives, of good and of evil. Nothing has played a part more exciting than that enacted by the fascinating loops, whorls, and arches etched on the fingers of a human being.

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*United States Department of Justice, Federal Bureau of Investigation, The Science of Fingerprints: Classification And Uses.
For sale by Superintendent of Documents,
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CHAPTER II

Types of Patterns and Their Interpretation

The Science of Fingerprints: Classification And Uses.

Types of Patterns

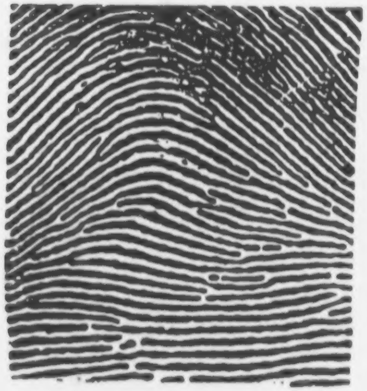
Fingerprints may be resolved into three large general groups of patterns, each group bearing the same general characteristics or family resemblance. The patterns may be further divided into sub-groups by means of the smaller differences existing between the patterns in the same general group. These divisions are as follows:

I. ARCH
- *a.* Plain arch.
- *b.* Tented arch.

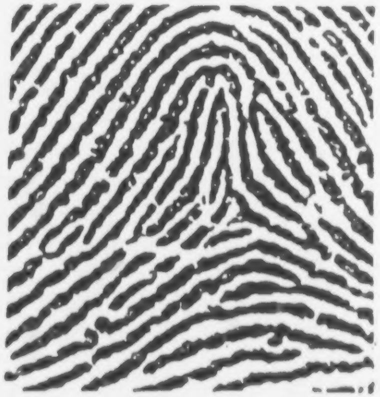
II. LOOP
- *a.* Radial loop.
- *b.* Ulnar loop.

III. WHORL.
- *a.* Plain whorl.
- *b.* Central pocket loop.
- *c.* Double loop.
- *d.* Accidental whorl.

Illustrations 1 to 10 are examples of the various types of fingerprint patterns.



1. Plain arch.



2. Tented arch.

How Fingerprints Are Classified. Fingerprint experts classify fingerprints according to classification formulas. Most of these formulas are based on fingerprint patterns and on the number of ridges between points within the patterns.

Every fingerprint belongs to one of four major types of patterns. In a loop pattern, the most common type, the ridges begin on one side of the finger, curve back sharply, and end on the same side. The ridge in a whorl pattern have a circular or spiral form. In an arch pattern, the ridges extend from one side of the finger to the other, rising slightly in the center. An accidental pattern has no specific form. Many accidental patterns combine loops, whorls, and arches.*

Excerpted from The World Book Encyclopedia.
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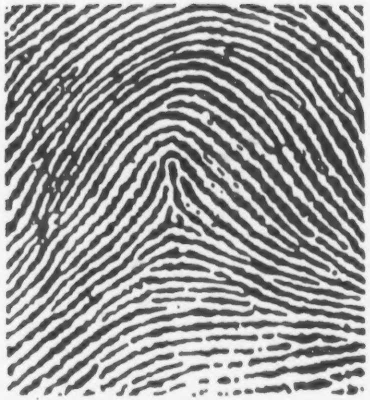
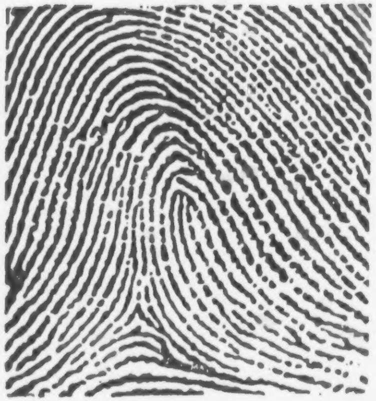
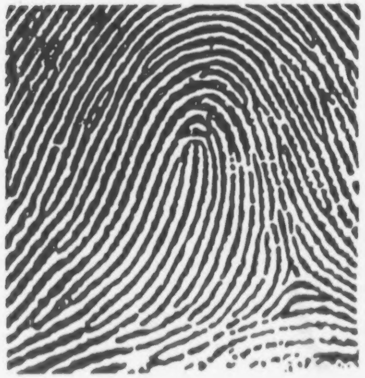


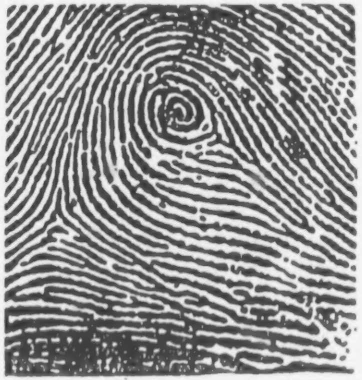
3. Tented arch.



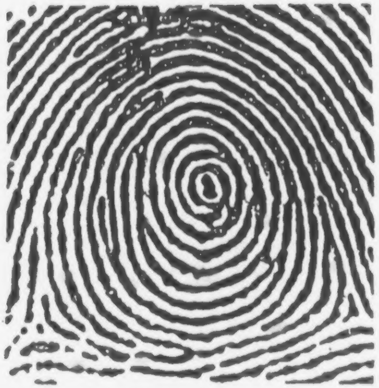
4. Loop.



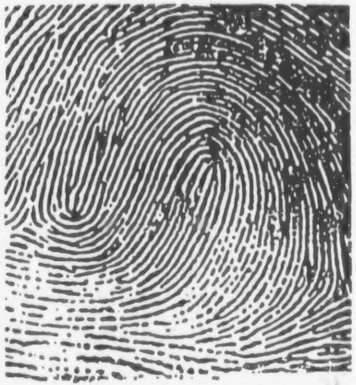
5. Loop.



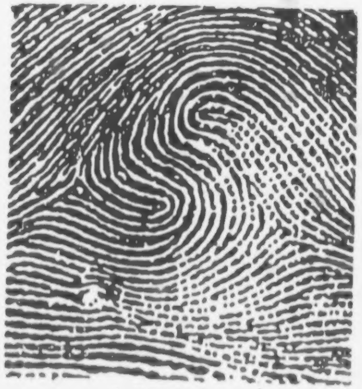
6. Central pocket loop. (Whorl



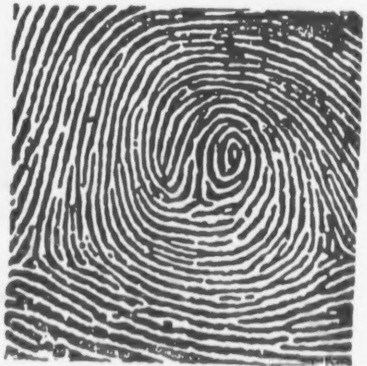
7. Plain whorl.



8. Double loop. (Whorl)



9. Double loop. (Whorl)



10. Accidental. (Whorl)

ACTIVITY 3: MORE INVOLVEMENT IN USING THE BASIC SCIENCE PROCESSES IN HANDS-ON ACTIVITIES

This sequence is to be conducted like Activity 2. You may wish to regroup participants before they work on another series of multilevel activities and again use most of the basic science processes.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Give instructions for activities and organize five groups of participants to work on them.
2. Supervise and interact as participants follow written directions and discuss classroom applications.
3. Lead a discussion in which participants share their results.

MATERIALS LIST

For each participant:

1 copy Teaching Aid 1
1 copy Cards 1-5

For group work:

Body Measures II (Card 1)

2 2m tapes or meter sticks
5 sheets plain paper
Watch with second hand from Body Measures I set up

Candle Jars II (Card 2)

3 jars, candle stubs, and pans from Candle Jars I set up
1 roll masking tape
10 paper towels
5 sheets plain paper

Bouncing Balls

1 tennis ball
1 golf ball
2 meter sticks
5 sheets plain paper

Weather Data (Card 4)

1 copy Teaching Aid 2
3 thermometers
2 rubber bands
1 empty 1/2 gallon milk carton
1 small piece cotton rag
1 spool thread
5 sheets plain paper

Classification II (Card 5)

Approximately 20 small objects (paper clips, marble, piece of sponge, penny, nickel, dime, strip of brass or copper, pencil, nail, bit of styrofoam, bits of paper and cardboard, etc.)
2 magnets
Dry cell
60 cm wire
1 small light bulb and socket
Electricity conduction device as pictured (2 iron nails, small block of wood)

ADVANCE PREPARATION

Prepare the electricity conduction device as pictured in Classification II.

TEACHING SEQUENCE

1. Organize five different groups. Each group should select a leader, a recorder, and a reporter. Distribute Teaching Aid 1 and Cards 1-5 and give participants a few minutes to skim the activities. Ask them not to look at the backs of the activity cards at this time. Let groups select an activity, get their supplies, and move to a specified area of the room to work.

2. Circulate and help with problems and questions. If things are proceeding smoothly, just encourage the participants. As problems arise, try to help solve them.

3. Lead a discussion in which participants share what they learned and comment on the items on Teaching Aid 1. Help participants evaluate their recording of results, as before, by the use of these questions:

   a. Were your charts or graphs entitled?

   b. Were your rows, columns, or axes labeled?

   c. Did you use a suitable, uniform scale where applicable?

   d. Are results legible?

   d. How else might the data have been shown?

Invite participants to ask questions or offer additional comments and reactions. Allow time for final cleanup.

USING THE BASIC SCIENCE PROCESSES IN ACTIVITIES

Children can use the science processes -- observing, measuring, communicating, classifying, predicting, and inferring -- in simple hands-on activities. They gain knowledge as they work with the activities, but they also develop skills in using the processes. As you work with several activities, you will have an opportunity to use most or all of the basic science processes.

General Directions

1. Choose and carry out one of the activities that is described on Cards 1-5.
2. Work together to analyze the activity and answer the following questions:
    a. What did you observe? What characteristics of observation did you employ as your worked? (Direct observation, use of senses, acting on object as appropriate.) What quantitative and qualitative data did you gather?

    b. How did you communicate as you carried out the activity? What different forms of communication did you use (oral or written language, graphs, charts, body language)?

    c. What predictions did you make during the activity?

    d. Did you work with any time and space relationships? What were they?

    e. What inferences did you make? Did any results surprise you?

    f. What content did you learn? What would children learn from the activity? What questions could you use to guide and enhance the students' learning?

    g. Compare your results on questions a-f with the written comments on the back of your activity card. Add other comments and write down your suggested questions for children. Add some ways to extend your activity to the back of the activity card.

    h. What grade level do you think the activity is on? How might you modify the activity to make it simpler or more sophisticated to meet the needs of younger or older children?

    i. What safety factors should be considered in your activity?

    j. You worked in a small group on your activity. How could you modify the activity so that every student in a class of 25 to 30 children could be involved?

   k. How could children be involved in gathering equipment or cleaning up?

   l. Add other pertinent comments.

3. Plan to report to the other participants briefly showing and describing what was involved in your activity and highlighting answers to the above questions.

4. Clean up your area as much as possible, but save enough equipment and results to make your report to the other participants clear. After the final discussion, finish cleanup and return all equipment to its original place.

WIND RELATED CHARTS

BEAUFORT SCALE OF WIND FORCE

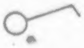
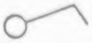
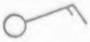
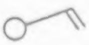
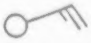
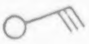
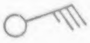
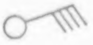
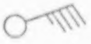
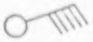
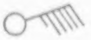
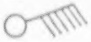
Beaufort Number	*Wind Effects*	*Miles per Hour*	*Weather Bureau Description*	*Symbol on Weather Map*
0	Calm; smoke rises vertically.	Less than 1	Calm	○
1	Direction of wind shown by smoke drift, but not by wind vanes.	1–3	Light air	
2	Wind felt on face; leaves rustle; ordinary vane moved by wind.	4–7	Slight breeze	
3	Leaves and small twigs in constant motion; wind extends light flag.	8–12	Gentle breeze	
4	Raises dust and loose paper; small branches are moved.	13–18	Moderate breeze	
5	Small trees in leaf begin to sway; crested wavelets on inland waters.	19–24	Fresh breeze	
6	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	25–31	Strong breeze	
7	Whole trees in motion; inconvenience felt in walking against wind.	32–38	High wind	
8	Breaks twigs off trees; generally impedes progress.	39–46	Gale	
9	Slight structural damage occurs (chimney pots and slate removed).	47–54	Strong gale	
10	Seldom experienced inland, trees uprooted, considerable structural damage occurs.	55–63	Whole gale	
11	Very rarely experienced; accompanied by widespread damage.	64–75	Storm	
12	Great damage.	Above 75	Hurricane	

Figure 17–11 The Beaufort Scale of wind force.

Relative Humidity (Percentage) – °C

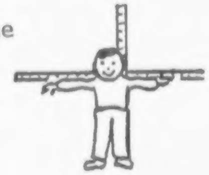
Temperature of Dry Bulb (°C)	*Depression of the Wet Bulb (°C)*														
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*12*	*14*	*16*	*18*	*20*
50	94	89	84	79	74	70	65	61	57	53	46	40	33	28	22
45	94	88	83	78	73	68	63	59	55	51	42	35	28	22	16
40	93	88	82	77	71	65	61	56	52	47	38	31	23	16	10
35	93	87	80	75	68	62	57	52	47	42	33	24	16	8	
30	92	86	78	72	65	59	53	47	41	36	26	16	8		
25	91	84	76	69	61	54	47	41	35	29	17	6			
20	90	81	73	64	56	47	40	32	26	18	5				
15	89	79	68	59	49	39	30	21	12	4					
10	87	75	62	51	38	27	17	5							

Figure 17–12 Chart of relative humidity. The depression of the wet bulb is the difference between the wet and dry bulb readings.

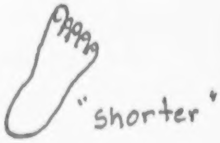
Adapted from Jacobsen and Bergman, Science For Children (Prentice Hall, 1980), p. 378 & 379.

Teaching Aid 2

Body Measures II



1. Use the measuring tape or meter sticks. Determine and record the height of each group member. Measure and record the arm span of each group member. Compare each person's height and arm span.
2. For each person, compare the length of the big toe and second toe. Record whether the second toe is longer, shorter, or about the same length as the big toe.
3. Record each person's pulse rate per minute. Predict what will happen if you exercise for two minutes, then take the pulse rate again. Exercise for two minutes, then record pulse rates again.
4. Make some inferences based on the data above.
5. Create some interesting and informative ways to show your data.



Card 1a

Body Measures II

Science Processes Used: Measuring, observing, communicating (oral and written forms), predicting, inferring, using time and space relationships.

Concepts: People's heights, arm spans, and toe "arrangements," and pulse rates vary. People's heights and arm spans are approximately equal. Exercise increases pulse rate to varying degrees.

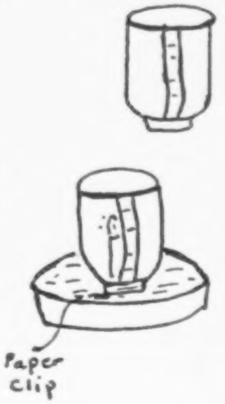
Ways to Extend the Activity: Use other body measurements. Compare measurements by sex. Test a well-conditioned athlete's pulse rate before and after exercise. Find the mean height or pulse and show each person's deviation from the mean.

Suggested Questions for Children:

Card 1b

Candle Jars II

1. Use the jars from the Candle Jars I activity. Each is marked with its approximate capacity. Attach a piece of masking tape to each jar as shown.
2. What will happen if you light a candle standing in a jar of water, then place an inverted jar over it? Make some predictions and try them out following these procedures. Drip some candle wax into the pan, then set the candle in the melted wax, thus attaching the candle to the pan. Place a paper clip near the candle so that when you place the jar over the candle, the paper clip will hold the jar's rim up just a bit from the bottom of the pan. Carefully pour water into the pan to a depth of 2-3 cm.
3. Now make some measurements. Predict how long each candle will burn under each of the jars. Light the candle. Place an inverted jar over the can. Mark the water level on the tape. Do three trials for each jar and get the average. In between trials, wipe out the jars and swish them through the air.
4. Make some inferences.
5. Show your data in some interesting and informative ways.



Card 2a

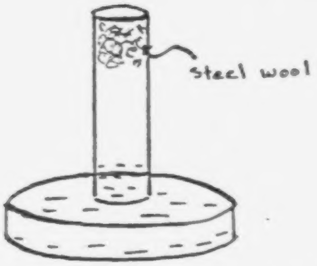
Candle Jars II

Science Processes Used: Measuring, observing, communicating, predicting, inferring, using time and space relationships.

Concepts: See Candle Jars I. Also as oxygen within the jar is consumed by burning, the air pressure within the jar is lessened. The greater air pressure outside forces water into the jar. The water fills about 1/5 of the jar--the oxygen that was burned was about 1/5 of the total amount of air in the jar.

Ways to Extend the Activity: Use different sized jars and candles. Put damp steel wool in a narrow jar. Invert the jar over water. As the steel wool oxidizes (rusts), water also rises in the jar.

Suggested Questions for Children:



Card 2b

Bouncing Balls

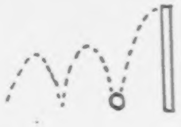
1. Use two different kinds of balls. See how many times one ball will bounce on a smooth surface before coming to rest when dropped from different heights.

2. One person should drop one ball from heights of .5 m, 1 m, and 1.5 m. Other group members should count the number of bounces heard and seen. Predict how many times the ball will bounce when dropped from a height of 2m. Try it out. Record results.

3. Repeat the procedure with the second ball.

4. Make some inferences.

5. Show your data in some interesting and informative ways.



Card 3a

Bouncing Balls

Science Processes Used: Measuring, observing (by sight and hearing), communicating, predicting, inferring, using time and space relationships.

Concepts: The number of times a ball bounces is related to its composition, the surface on which it is dropped, and the height from which it is dropped.

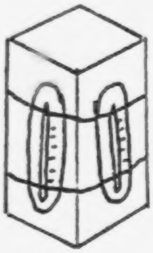
Ways to Extend the Activity: Use different balls and make comparisons; use different surfaces.

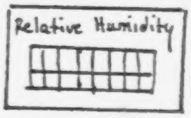
Suggested Questions for Children:

Card 3b

Weather Data

1. Set up a wet and dry bulb thermometer device to test for relative humidity (see directions below). Predict the approximate relative humidity. Use the device and chart to determine the approximate relative humidity.
2. Predict the approximate wind speed in km/h. Use Teaching Aid 2 to determine the approximate wind speed.
3. Predict and take the temperature indoors and outdoors in degrees Celcius.
4. Think of as many descriptive words as you can for today's weather.
5. Show your data in some interesting and informative ways.

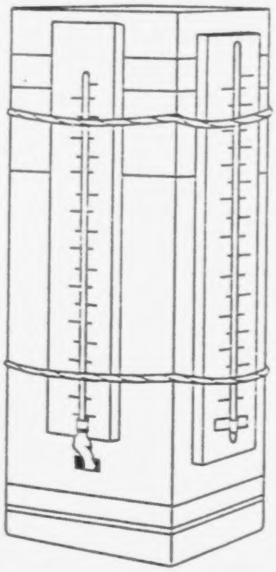




Card 4a

Directions for Making a Simple Hygrometer... to Measure Approximate Relative Humidity

Cut a hole about 5 cm from the bottom of a half gallon milk carton, as shown. Carefully wrap the end of a 4 x 10 cm piece of rag around the end of the bulb of a small inexpensive thermometer. Tie the rag in place with thread. Attach the two thermometers with rubber bands, as shown. Insert the end of the rag in the hole. Pour a small amount of water into the bottom of the milk carton. The water around the wet bulb will evaporate and cause a lowering of temperature. Read both thermometers. Use the chart below to determine the approximate relative humidity.



A hygrometer, an instrument for the determination of relative humidity.

Weather Data

Science Processes Used: Measuring, observing, communicating, predicting, using time and space relationships.

Concepts: Weather can be described in many ways. Instruments help us measure aspects of the weather.

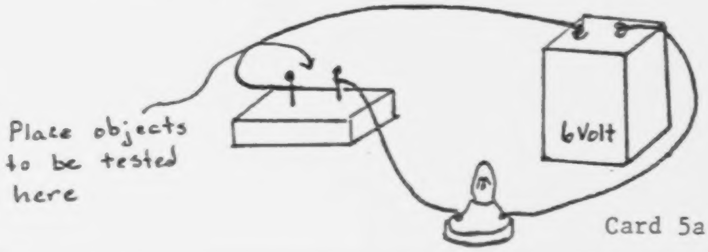
Ways to Extend the Activity: Gather and display weather data over a period of time. Compare your weather data to that reported on TV or in the newspaper. Have your class give a weather report on the school intercom or to another class. Find out how to measure barometric pressure. Predict tomorrow's weather and check your predictions.

Suggested Questions for Children:

Card 4b

Classification II

1. You will do two classification exercises.
2. Work with the materials and see which ones
   a. attract to a magnet and
   b. conduct electricity.
3. First, arrange the materials into two groups - materials that you predict are magnetic and nonmagnetic. Test out the materials. You might also test some gold or silver jewelry. Make some subgroups. Record your results in an interesting way.
4. Next, divide the materials into two different groups--ones you predict will be conductors and nonconductors of electricity. Test out your predictions. Use the set up as illustrated. Record your results in an interesting and informative way.
5. Compare your results. Make some inferences.
6. Did you observe or measure as you worked?



Card 5a

Classification II

Science Processes Used: Observing, predicting, classifying, communicating.

Concepts: Only certain metals (iron, steel, nickel, cobalt) attract to magnets. Most metals conduct electricity.

Ways to Extend the Activity: Gather and test other materials for magnetic attraction and conduction of electricity. Identify materials that are both magnetic and conductors of electricity.

Suggested Questions for Children:

Card 5b

TOPIC 3: EXPLORING THE INTEGRATED SCIENCE PROCESSES

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University of Southern Mississippi

In the recently published "Philosophy and Aims of Teaching Science in Mississippi," the integrated processes of controlling variables, defining operationally, interpreting data, and experimenting were identified as skills that students need to develop in science. The term "integrated" is used as a descriptor for these processes because combinations of the basic processes, i.e., observing, inferring, classifying, measuring, using space/time relationships, predicting, and communicating (Topic 2), are inherent skills for this more complex level of information gathering and processing. The ultimate process of science, experimenting, which has been so fruitful in the advancement of the scientific knowledge base, generally requires skill in all the processes, both basic and integrated.

The integrated processes are usually taught to children in the intermediate grades after they have a foundation in the basic processes. Children acquire understanding of and skill in the use of the processes by being actively engaged in the processes. Likewise, workshops for in-service training of teachers must actively involve the teachers in "doing" the processes of science.

Since experimenting involves all the component process skills, a conceptual understanding of the characterizing attributes of an experiment needs to be understood by elementary science teachers. An experiment involves seeking an answer to a question under controlled conditions. Usually the question arises out of observations of some natural phenomenon that sparks an interest in the observer. Typically a hypothesis is formulated as a tentative statement of what the observer predicts will happen when an answer is sought to the question under controlled conditions. The subsequent steps involve identifying the variables to be controlled, making operational definitions, planning measurements and other test procedures, carrying out the test, collecting and interpreting the data, and rejecting or accepting the hypothesis. These steps are what is generally described as the scientific method.

The beginning workshop activity is designed to develop a conceptual understanding of experimenting by engaging the participant teachers in an experiment with a simple physical system, a freely swinging pendulum. Once this conception is developed, component skills needed for proficiency in experimenting are addressed in subsequent activities.

Much time for practice and refinement of skills is needed for proficiency in using and teaching the integrated processes. These activities will provide teachers a foundation for developing proficiency and will motivate teachers to actively engage in experimenting with their students.

ACTIVITY 1: EXPERIMENTING WITH SWINGING PENDULUMS

This activity is designed to engage the participants in each of the integrated processes as they plan and conduct a simple experiment using pendulums. Several key concepts necessary for understanding the process of experimenting are introduced.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader's behaviors in summary form are as follows:

1. Introduce the term "integrated processes."
2. Use swinging pendulums as a means of establishing a question for experimenting.
3. Engage participants in stating a hypothesis and in identifying the independent, dependent, and controlled variables.
4. Plan with participants the data gathering procedures and operationally define key terms.
5. Organize and engage participant groups in testing the hypothesis.
6. Involve participants in reviewing key terms and the steps taken in conducting the experiment.

MATERIALS LIST

For each group of four participants:

1 large clock with a second hand
1 one-meter length of fishing line
3 pendulum bobs (heavy washers, bolts or lead sinkers)
1 paperback book without protruding bindings
1 meter stick
1 strip of masking tape
1 large gem clip

ADVANCE PREPARATION

Cut 1 meter lengths of fishing line sufficient for the number of participant groups. Tie a large gem clip to one end of the fishing line on which to hang pendulum bobs. Collect objects uniform in size, material, and weight to use as pendulum bobs. The weight of the pendulum bob can be adjusted by hanging a different number of the objects on the gem clip fastened to the fishing line. To swing the pendulum, slide the fishing line between the pages of a paperback book, adjust the length of the pendulum as desired, place the book on the edge of a desk or table, hold the book in place and start the pendulum swinging.

TEACHING SEQUENCE

1. Use information provided in the introduction to Topic 3 to introduce the participants to the integrated processes. Distribute Process Skills-AAAS Listing (Teaching Aid 1), which defines the processes of science. Follow by explaining that the first activity will involve them in the use of several of the basic as well as integrated processes and will help them to better understand the characterizing attributes of a true experiment.

2. Display two pendulums with bobs of different weights suspended from strings of different lengths. Ask the participants if they think the bobs will swing at the same or different rates when set into motion. Raise and release the bobs from different heights and allow the participants to observe their motion. After a few minutes, ask the participants if the bobs swung at the same or different rates.

   Solicit from the participants and list on the chalkboard the factors they suggest as possible influences on the rate of swing. Suggested variables might include:

   - the length of the string
   - the weight of the bob
   - the height to which the bob was initially displaced or the angle of release
   - the force applied at release

   When the list is adequate, label the list of factors with the word "variable." Define "variable" as any factor that may vary or change within a system. Point out that variables are not names of objects, i.e., the string, the bob, but measurable properties related to objects making up the system that may be changed or varied. Variables must be described, not simply named. (Children have to be taught to describe variables.) Further explain that the process of experimenting involves isolating a single variable and studying the effect of changes in that variable upon some other variable about the system while controlling for all other variables. With that in mind ask the participants to formulate questions that might be answered through experiments about the effects of the different listed variables on the motion of the pendulum. Write several of the participants' suggested questions on the chalkboard, then label the list "Problem Statements." Explain that all experiments begin with a problem to be solved which customarily can be stated in the form of a question to be answered.

3. Select one of the questions as a problem statement to be tested. Ask the participants what they think will happen to the motion of the pendulum when the particular variable in that question is changed. (The question might be "What will happen to the rate of swing of the pendulum when the weight of the bob is changed?") Write the statement that emerges from the participant input on the blackboard and point out that the statement predicts the outcome of the experiment. A statement predicting the outcome of an experiment is called a hypothesis.

Ask the participants to examine the hypothesis and identify the variable being tested and write their response on the blackboard. (Make sure that the variable is fully described, not just "string" for "length of string.")

Label their response the independent or manipulated variable. Explain that the variable being tested is usually referred to as the independent variable in research publications; however, the term manipulated is generally used in elementary school science. Next, ask the participants to identify the variable in their statement of a hypothesis that would respond to the changes in the independent variable. Write their response on the blackboard and label it the dependent or responding variable. The term "responding variable" is usually used with children to prevent the children from becoming confused by the very similar terms "independent" and "dependent."

Explain that in testing a hypothesis there are three kinds of variables--a variable being tested (independent), a variable which is allowed to respond to the test (dependent), and variables which must be held constant or under controlled conditions in order to make a fair test. Ask the participants to identify the variables that would need to be kept the same to test their hypothesis. Record their list on the chalkboard beneath the heading "Controlled Variables." (A controlled variable is any factor which is held constant or allowed to fluctuate the same way across all treatments in order to make a fair test. The length of string might be held constant, whereas the temperature in the room might fluctuate the same way as testing proceeds.)

4. Involve the participants in determining the measurements needed and procedure to follow in testing the hypothesis. Point out the need for repeated measurements in testing the hypothesis. In planning the data collection procedure, the need for operationally defining several terms will arise. Competence in defining operationally is of critical importance in the precise use of terms in communicating about investigations and experiments. In the physical sciences, operational definitions are stated in terms of "what you do or what operation you perform" and "what you observe." In this experiment the following terms might be operationally defined as follows:

Swing of a pendulum - Pull a pendulum bob back from its rest position, release the pendulum bob, and observe the bob return to the point of release. This back and forth movement is one complete swing of a pendulum.

Rate of swing - Count the number of complete swings in a measured amount of time. Write the number of swings over the time (40 swings/minute).

Period of a pendulum - Count the number of swings in a measured amount of time and divide the time by the number of swings to find the amount of time for one complete swing.

In planning the data collection, you might suggest counting swings for 15 second intervals. The number of swings could then be multiplied by 4 to get the swings per minute. Participants should be encouraged to run several trials and average data from the repeated trials in order to reduce error in counting and timing.

5. Organize the participants in small groups for collecting the data. Demonstrate how to use materials prepared for testing the hypothesis. Explain that the data collected by each group should be recorded in a table (Record Sheet, Teaching Aid 2) and then a graph constructed. Point out that the scale for the independent variable should be placed on the "x" axis and the scale for the dependent variable on the "y" axis.

   After collecting and graphing the data, the participants should be able to interpret the results and decide if the hypothesis should be accepted or rejected.

   Continue testing variables until it becomes clear that the length of the string determines the rate of swing. Be sure to state a hypothesis each time a different variable is tested.

6. Close the activity by reviewing with the participants the steps taken in conducting the experiment. Ask them to enumerate the defining attributes of a true experiment. Use a questioning sequence to assess their understanding of key concepts: variable, independent variable, dependent variable, controlled variable, hypothesis, and operational definition.

   Suggested questions are:

   1. Chapter 22, pp. 291-305, Gateways to Science, Grade 4, has a chapter devoted to the motion of pendulums. The term variable is defined in that chapter as "the part of an experiment that changes." What is your evaluation of the appropriateness of that definition?

   2. Choose which is the better operational definition and defend your choice for the following terms.

      Pressure:

      (a) Measure the total force and divide the measurement by the measurement of the area on which the force is applied. The quotient is a measure of the pressure.
      (b) How hard something is pressing.

      Small calorie:

      (a) A unit of heat.
      (b) The amount of heat that increases the temperature of one gram of water 1°C.

Good conductor of electricity:

(a) A good conductor of electricity is any object which can be used to complete an electric circuit.
(b) A wire is removed from an arrangement of batteries, wires, and light bulb, in which the bulb is glowing and the light bulb goes out; if an object is used to replace the wire and the light goes on again, the object is a good conductor of electricity.

3. Why is it necessary to operationally define terms in experimenting?

4. Suppose you wished to determine if changing the water temperature would affect the breathing rate of a goldfish; what would be the independent variable for your experiment? dependent variable? What variables would need to be controlled?

5. What is the function of a hypothesis in an experiment?

PROCESS SKILLS-AAAS LISTING

Basic Processes

OBSERVING: A process in which one or more of the senses (sight, smell, touch, hearing, and taste) are used to identify and name the properties of objects and interactions.

USING SPACE-TIME RELATIONSHIPS: A process in which a child states the locations and shapes of objects or describes the positions and changes in position of moving objects.

CLASSIFYING: A process in which observable properties are used to sort (categorize) objects. If the properties to be employed as criteria for categorizing the objects are not supplied, they must be selected prior to the sorting activity.

USING NUMBERS: A process skill where the learner finds the quantitative relationships among data.

MEASURING: A process in which instruments are used to quantify observations. The dimensions of an object being observed can be determined by comparing the object to a standard unit of measurement and counting the number of standards found within the unknown.

COMMUNICATING: A process in which compiled information is used to describe a system consisting of objects and/or interactions. The description of these systems can be represented through oral, written, pictorial, or graphical form.

PREDICTING: A process in which future events are forecast from trends found within a solid base of evidence. These events can fall within collected data (interpolation) or beyond the scope of the data (extrapolation).

INFERRING: A process in which speculations are developed to account for observations. These speculations may be strongly influenced by past experiences.

Integrated Processes

HYPOTHESIZING: The child predicts relationships that exist between two variables. Hypotheses generally imply an experimental test that may be performed to verify them.

CONTROLLING VARIABLES: The child controls variables while experimenting so that a single variable is manipulated, and a single variable responds to manipulation. This skill is associated with structured tests of the hypothesis.

DEFINING OPERATIONALLY: Operational definitions simply describe a system in terms of what one can observe. This skill is essentially a composite of observation and communication skills.

INTERPRETING DATA: Interpreting data is a composite skill consisting of communicating, predicting, and inferring. The child uses the data collected to accept or reject hypotheses he may have in question.

EXPERIMENTING: "Experimenting is the process that encompasses all the basic and integrated processes." The child is manipulating material. This skill may involve trial and error manipulation of the discovery activity or the organized testing of a hypothesis.

Record Sheet

Variable	No. of Swings per 15 Seconds			Average	Swings per Minute
	Trial 1	Trial 2	Trial 3		

The variable tested (manipulated) ______________________________

____

Responding variable ______________________________

The variables controlled (kept the same for each trial) were

____

____

____

The experiment showed that ______________________________

____

____

____

____

____

Teaching Aid 2

ACTIVITY 2: CONTROLLING VARIABLES -- UPWARD MOVEMENT OF LIQUIDS IN MATERIALS

In this second activity, the process of controlling variables is emphasized. The participants again identify variables that might influence a simple system and conduct experiments in which variables are controlled. Variables will again be described as independent (manipulated), dependent (responding), or controlled. The activity will reinforce concepts introduced in Activity 1 and provide for practice in using the integrated processes.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader's behaviors in summary form are as follows:

1. Introduce the activity with a demonstration involving water movement up paper strips.
2. Solicit a list of variables that were held constant in the demonstration.
3. Involve participants in asking questions related to changes in the variables on their list which would be suitable for experimenting.
4. Organize participants in groups for planning and conducting experiments.
5. Involve participants in reporting results.
6. Introduce another factor, a green dot of food coloring on the paper strips, to be investigated.
7. Involve participants in designing and carrying out additional experiments using food coloring on paper strips.
8. Have participants report findings.
9. Relate the process of experimenting to teaching science content.

MATERIALS LIST

For each group of four participants:

1 sheet filter paper (24 cm diameter)
2 sheets brown paper towels (institutional type)
1 sheet of blotting paper (5" x 8")
1 pair of scissors
1 metric ruler
4 clear, plastic vials
1 bottle of green food coloring
1 bottle of red food coloring
1 black, water soluble ink pen (Flair type)
4 assorted colors of water soluble ink pens (Flair type)
1 thermometer
4 toothpicks or paper clips

For a large group, use as needed:

1 bottle denatured alcohol
1 large clock with second hand

ADVANCE PREPARATION

Precut about 10 strips (2 cm x 12 cm) from each type of paper. Arrange all materials on a table accessible to all participants. Prepare filter paper strips and two vials with water for the introductory demonstration.

TEACHING SEQUENCE

1. Place two identical strips of blotting paper (2 x 12 centimeters) and two large plastic vials, each containing the same amount of water (about 2 centimeters in depth), on a table in full view of the participants. Ask the participants to predict what will happen if each strip is immersed in the water to the same depth and left in the water the same length of time. From previous experiences, the participants will probably predict that water will move up the strips to about the same height in both papers. Test their prediction by having a participant mark each strip with a pencil line one inch from the bottom, lower each strip in water to the pencil line, and hold in the water for 30 seconds. Allow the participants to observe the strips while they are in the water and after they are taken out. Discuss the results. Ask, why are the water lines at about the same height in both papers. They will probably point out that, as far as they can determine, everything was the same; thus, the water should rise at the same rate in both strips of blotting paper. Point out that a fundamental belief in modern science is the reproducibility of nature. In other words the results of two experiments will be the same if experimental conditions are identical. If the results are not the same, some factor in the experiments must have varied, thus influencing the outcome.

2. Solicit from participants and list on the chalkboard the variables which were kept the same in testing the movement of water up the paper strips. A good list might include:

    1. The size of the strips

    2. The shape of the strips

    3. The distance strips were immersed in the water

    4. The material in the strips

    5. The color of the strips

    6. The amount of water in the vials

    7. The temperature of the water

    8. The time the strips were held in the water

3. Point out that in this situation all of the variables were held constant. Now have the participants suggest questions to consider related to what might happen if they manipulated the variable. These are some examples they may think of:

    1. Would the water line be the same if the strips of paper differed in width? What effect does the width of the paper strip have on the rate at which water rises? Does the rate at which water rises depend on the width of the blotting paper?

    2. Would the water line be the same if the strips of blotting paper were dipped in the water to different depths? or How does the rate at which the water rises depend on the depth of the blotting paper under water?

    3. Does the rate at which the water rises depend on the type of material the strips are made of?

    4. Would the water line be the same if the pieces of blotting paper were left in the water for different amounts of time?

    5. How does the height of the water line depend on the temperature of the water?

    6. Would the water line be the same if the color of the two strips of blotting paper were different?

4. Organize the participants in groups of 4 to examine some of the questions they have posed. Before collecting data, have the participants outline their procedure, including in the outline the following:

    1. Statement of a hypothesis

    2. Description of the independent, dependent, and controlled variables

    3. Plan for data collection

    Make available the materials needed for their experiments and let them proceed on their own to make their tests. Caution that they must control all except two variables; manipulate one of these two variables in some way; and make observations or measurements to find out how the remaining variable responds. (They should be able to conduct their investigation quickly. The investigations are simple experiments appropriate for use with children.)

5. After the experiments are completed, have each group report their results. Allow participants to ask questions about testing procedures and conclusions. Stress the importance of controlling the variables.

6. Place a small dot of green food coloring on a filter paper strip (2 cm x 10 cm) about 4 cm from the bottom of the strip. Pour water into a large pill vial to a depth of three centimeters. Insert a toothpick through the paper strip and suspend the strip across the mouth of the pill vial so the bottom of the strip will be immersed in the water below the green dot.

Ask the participants to predict what will happen to the green dot when the strip is lowered in the water. Let them observe what happens and talk about their observations.

7. Now suggest that out of their observations they formulate a question for experimenting. Again, the participants may work in groups. Let them plan their experiments and proceed with minimal guidance from you as the workshop leader. Assist with obtaining materials. Listen to their plans, making sure that they have planned ways of controlling variables.

   Some variables that might be manipulated are:

   1. The type of paper used
   2. The temperature of the water
   3. The color of the food coloring
   4. The type of liquid used
   5. The shape of the paper strips
   6. The time immersed in water

   Have materials available for a variety of investigations.

8. Allow the groups to describe their experiments and report results. Reinforce terms such as manipulated variable, responding variable, and controlled variables, as opportunities arise.

9. To illustrate that experimenting can be used to teach science content as well as skills, a questioning sequence focusing on the development of knowledge (facts, concepts or generalizations) might be used.

   - Is green food coloring made up of one or more than one kind of particle?
   - How many different kinds of particles are in green food coloring?
   - What evidence supports that number?
   - Why can't you determine how many particles are present by simply looking at the food coloring?
   - How could you prove that the yellow and blue parts on the paper came from the separation of the green food coloring into parts?
   - If matter were not made up of particles, could this separation have occurred?
   - The term "pure substance" is used for matter consisting of one kind of particle; whereas, the term "mixture" is used for matter composed of two or more kinds of particles, each of which keeps

its own characteristic properties. Which term correctly categorizes green food coloring?

- Can you be sure that the green food coloring did not exist as a single type of particle (pure substance) initially and separated into two smaller particles?

(Note: This questioning sequence is not appropriate for use with grade-school children. Some of the questions would be appropriate; others are too difficult. The intent is to illustrate how experimenting can be used to develop skill, as well as conceptual understanding.)

ACTIVITY 3: ASKING APPROPRIATE QUESTIONS FOR EXPERIMENTING

The intent of this activity is to help participants recognize that some questions cannot be answered through experimenting. Indeed, some questions are beyond the realm of science to investigate. Participants are asked to select from a series of questions those appropriate for experimenting. Further, they are involved in rephrasing any questions which are too broad in scope or otherwise not clearly delineated as problem statements for controlled experiments.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader's behaviors in summary form are as follows:

1. Introduce the activity with examples of appropriate and inappropriate questions for experimenting.
2. Involve participants in assessing the suitability of sample questions for experimenting.
3. Organize participants for group interaction related to questions assigned for their assessment.

MATERIALS LIST

A transparency prepared from Teaching Aid 1, Select the Questions Appropriate for Experimenting

A copy of Teaching Aid 2, Exercise In Asking Questions Appropriate for Experimenting, for each participant

ADVANCE PREPARATION

Prepare a copy of Teaching Aid 2 for each participant.

Make a transparency from Teaching Aid 1. Review the teaching sequence.

TEACHING SEQUENCE

1. Use the following paragraphs to introduce the activity:

> Asking the right question is perhaps the most important step in the pursuit of science. Questions for experimenting arise from observations made directly by the experimenter or described by someone else about the natural environment. A characterizing attribute of science is that it is based upon observable evidence. Some questions obviously are outside the realm of science to pursue an answer. For example, "Shouldn't everyone be free to choose?" would not be answerable by a controlled experiment.

What kind of questions are appropriate for experimenting? In general, questions concerning cause-and-effect relationships about which directly observable evidence can be obtained and processed. For example, "What effect does amount of exercise have on the heart rate?" has a clearly identifiable cause-and-effect relationship. Notice that the cause, amount of exercise, is the independent variable and the effect, heart rate, is the dependent variable.

In contrast, the question, "Does air have weight?" is not suitable for an experiment. While the question also appears to be in a form suitable for experimenting and can be solved by direct observations, there is no cause-and-effect relationship to be explored. To answer the question samples of air could be weighed. The question, however, could be restated into a form suitable for experimenting by adding another variable. "What effect does temperature have on the weight of a sample of air?" is a question about cause-and-effect relationships which would require a controlled experiment. Indeed, the answer to that question was important in establishing the Law of Conservation of Mass.

2. Using Teaching Aid 1, involve participants in assessing the suitability of each question for classroom experimenting. Questions 1 and 2 would require observing the interactions of objects and classifying the objects. Questions 3 and 5 are concerned with the meaning of the concepts "camouflage" and "water cycle." Cause-and-effect relationships are not examined. Questions 4 and 7 involve cause-and-effect relationships; however, they are not well stated for experimenting. The questions are too broad in scope. Each possible factor would need to be investigated separately to determine its effect. Temperature, surface area, type of liquid, and rate of air flow are all factors influencing rate of evaporation. Likewise, there are many factors that influence the rate of seed germination. These questions should be rephrased, identifying one specific manipulated variable to be examined. Question 6 suggests a cause-and-effect relationship; however, it is not stated in a form appropriate for experimenting. It could be rephrased asking, "What is the effect of temperature on the weight of equal volume samples of water?"

3. Organize the participants in groups of 4-5 members. Distribute copies of Teaching Aid 2 to each participant. Suggest that each group select a discussion leader and a recorder. Assign three questions from the Exercise to each group to be evaluated for experimenting. Allow time for discussion within the groups. Follow-up with each group presenting their evaluation of the questions assigned to them. Encourage comments from the class at large.

SELECT THE QUESTIONS APPROPRIATE FOR EXPERIMENTING

1. What objects sink and what objects float?
2. What kind of objects are attracted to magnets?
3. What does it mean when we say an animal is camouflaged?
4. What factors affect the rate of evaporation of a liquid?
5. What is a water cycle?
6. Is cold water heavier than warm water?
7. What conditions are necessary for seeds to germinate?

Topic 3
Activity 3
Teaching Aid 1
(Transparency)

EXERCISE: ASKING QUESTIONS APPROPRIATE FOR EXPERIMENTING

STEP #1

Evaluate the questions assigned to your group as problems for controlled experiments. Begin by rating each question as written, using the following response key:

A. suitable as stated for experimenting
B. suitable but not well stated
C. not suitable for a controlled experiment

STEP #2

After rating each question according to the response key, continue assessing the question using the procedure that follows:

If you selected Response A:

If the question is appropriate as phrased for experimenting, you should be able to answer the following questions based on the problem posed in the question:

- What is the independent variable?
- What is the dependent variable?
- What procedure could be used to test the question?
- What variables would need to be controlled for a fair test?
- What measurements would need to be made?

If you selected Response B:

The question is appropriate for experimenting, but is too broad in scope or not well defined. Rephrase the question in a form more suitable, and answer the questions given above.

If you selected Response C:

Explain why the question is unsuited for a controlled experiment.

Questions to be Evaluated:

1. How does the shape of an ice cube affect its rate of melting?
2. What determines how strong an electromagnet will be?
3. Can people identify the food they eat if they cannot smell?
4. How does the terminal bud affect the growth of woody stemmed plants?
5. What factors influence the direction the wind blows?
6. In what temperature range are pill bugs more active?
7. Do plants grow faster in natural or store-bought fertilizer?
8. What shapes do spider webs have?
9. What factors influence the rate of sprouting in corn seeds versus bean seeds?
10. How can we make frost and dew?
11. What are some of the properties of carbon dioxide?
12. What is the relationship between the burning time of a candle and the volume of air in a closed container?

ACTIVITY 4: STATING HYPOTHESES

This activity is designed to help participants understand the characterizing aspects and function of a well-stated hypothesis for a controlled experiment.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Set up a demonstration to be observed.
2. Solicit plausible explanations for the demonstrated phenomenon.
3. Introduce the defining attributes and function of a hypothesis.
4. Involve participants in examining their explanations as tentative hypotheses to direct further data gathering.
5. Organize participants in small groups to discuss suitability of alternative hypotheses offered for a problem.
6. Involve participants in generating and refining hypotheses for a series of proposed problems.

MATERIALS LIST

2 small bottles with narrow openings
2 large clear containers (2 liter)
green food coloring
source of hot and cold water
copies of Teaching Aids 1 and 2 for each participant

ADVANCE PREPARATION

Make copies of Teaching Aids 1 and 2 for each participant. Review the steps in the Teaching Sequence. Prepare materials for conducting the demonstration.

TEACHING SEQUENCE

1. Set up the following demonstration:

> Place several drops of green food coloring in each of two small bottles. Fill one small bottle with hot water and the other small bottle with cold water. In full view of the participants, quickly submerge the bottle containing the hot water in a large, clear container of cold water and submerge the small bottle containing the cold water in a large container of hot water. Place a sheet of white poster board behind the containers, so the participants can observe the circulation of the colored water.

Ask the participants to observe the phenomenon.

2. Solicit from the participants a description of what they observed. Listen closely to what they report as observations. Probably some of the participants will immediately process the data and make inferences to account for the phenomenon. When this happens, say: "Thinking about observations leads scientists to seek causes for events. Was your statement an observation or an inference explaining the phenomenon?" If an explanation is not offered to account for the phenomenon, ask the participants to offer an explanation. Solicit several plausible explanations and list these as brief generalizing statements on the chalkboard or a transparency. Statements such as the following might be offered:

   - Hot water rises in cold water, and cold water sinks in hot water (infers liquids to be water at different temperatures).
   - When liquids of different densities are in contact with each other, the more dense liquid is pulled downward, and the less dense liquid is buoyed upward (infers liquids of different densities).
   - The direction and rate of flow of liquids in contact with each other are density dependent.
   - The rate and direction of flow of a liquid are temperature related.

3. At this point present the following introduction of the term "hypothesis."

> Human beings have an inborn propensity to look out for regularities, or have a need to find regularities. As we think about observations, we are led naturally to seek causes for events. Our working explanations for the causes of a phenomenon may be in general terms labeled a hypothesis. The impossibility of conducting science without hypotheses was recognized as early as 1749 by David Hartley when he wrote: "It is vain to bid an inquirer form no hypotheses."[1] Hypotheses are naturally generated in our processing of observations as we search for regularities.
>
> The most fruitful hypotheses for experimenting are simple, predictive, testable, relevant statements of cause-and-effect relationships. The hypothesis is really nothing more than a predictive statement of the relationship between the manipulated variable (cause) and the responding variable (effect) for the phenomenon under question.

---

[1] Tweney, Ryan D., Michael E. Doherty, and Clifford R. Mynatt (Ed.), On Scientific Thinking, New York: Columbia University Press, 1981, p. 81.

4. Engage the participants in examining their statements offered to explain observations made about the movement of the liquids in the containers. Have them identify the manipulated variable (cause) and the responding variable (effect) in the statements.

   Have the participants select the statement which they think is the best cause-and-effect explanation for the observations they made. Explain that this statement will serve as a hypothesis -- a preliminary conclusion formed by conjecturing about the observations. Having adopted a hypothesis temporarily as the most probable explanation, the next step is to use logical reasoning to decide what kind of data would be needed to test the hypothesis. Ask: What additional observations might need to be made to test this statement of a hypothesis? As the participants engage in this process, they should begin to understand that the function of the hypothesis is to give direction to data gathering related to the problem solution.

5. Organize the participants in groups of 4-5. Distribute copies of Teaching Aid 1, Selecting A Hypothesis Suitable For Testing. Allow 15 minutes to complete the exercise. Follow up with each group sharing their choice of the best hypothesis for testing and defense of their choice.

   Note:

   Number 4 is intended as the best statement of a hypothesis for the problem posed by Mrs. Crews. The manipulated variable (length of soaking time) and the responding variable (time for sprouting) are clearly described and the cause-and-effect relationship delineated. The next best statement for the problem is #3; however, the manipulated variable is not as clearly described in this statement. Hypothesis 6 is testable, but it doesn't deal with Mrs. Crews' question of the effect of soaking on sprouting. A different problem, the amount of water uptake of seeds and rate of plant growth, is introduced. Hypothesis 9 suggests a different manipulated variable, the amount of water for soaking, from that suggested in Mrs. Crew's question.

6. Distribute to participants a copy of Teaching Aid 2, An Exercise On Formulating Hypotheses. Each participant should be directed to work independently on the exercise, completing one hypothesis for each problem described. Allow 10-15 minutes for thinking and writing hypotheses. Organize participants in groups of 4-5 for examining the hypotheses generated. For these problems several alternative hypotheses of equal merit should arise. The focus of this exercise should be on the appropriate phrasing of a hypothesis to provide the direction necessary for data gathering in a controlled experiment.

EXERCISE: SELECTING A HYPOTHESIS SUITABLE FOR TESTING

At home after a busy day at school, Mrs. Crews was preparing the evening meal. As she drained water from the beans left soaking since early morning, she noticed that some of the beans had split lengthwise revealing tiny developing plant embryos. She wondered if soaking seeds before planting would reduce the sprouting time for young seedlings. Being ever in search of problems appropriate for her fifth-grade science class, she knew immediately that her "wondering" had the potential for an experiment. This might be just the right activity to enliven an upcoming plant unit.

The day before the plant unit was to begin, she started bean seeds soaking. Realizing that problems for experimenting are more productive if they arise out of the curiosity of the children, she planned to involve the children in examining the parts of a germinating seed. This would build the necessary background knowledge about seeds. With skillful questioning, she knew curiosity about the effect of soaking seeds on sprouting would be easy to arouse.

All went as planned and the children were excited about doing an experiment, but they had problems stating a hypothesis to be tested. Mrs. Crews wrote each hypothesis the children suggested on the chalkboard.

The hypotheses were as follows:

1. The more you soak seeds, the quicker they sprout.
2. Soaking seeds won't help them to sprout.
3. If seeds are soaked in water before planting, the length of time for sprouting is changed.
4. The length of time seeds are soaked in water before planting affects the time necessary for sprouting.
5. The longer seeds are soaked in water before planting, the faster the plants will grow.
6. The more water the seeds soak up, the faster the seeds will grow.
7. The days for seeds to sprout are shorter if they are soaked.
8. The seeds will rot if they are soaked before planting.
9. If seeds are soaked in different amounts of water before planting, the time for sprouting changes.

1. Review the hypotheses stated by the children keeping in mind these guidelines about well stated hypotheses for experimenting.

   Guidelines For Stating Hypotheses:

   a. The hypothesis is a predictive statement relating the manipulated variable to the responding variable.
   b. The function of the hypothesis is to provide direction for data gathering.

Teaching Aid 1

c. Any good hypothesis must be testable. There must be the possibility of making observations that would tend to confirm or disprove the explanation.
d. The hypothesis which has fewer complexities and assumptions--in a word, the simpler--is preferable to the more complicated one. It should not be too broad in scope to realistically investigate.
e. The hypothesis must be precisely stated.
f. The hypothesis is a generalization inferred from observable evidence and should be compatible with accepted knowledge unless it offers a better explanation.
g. The hypothesis must be relevant to the problem solution.

2. Select the hypothesis you think to be the best statement to guide the investigation and be prepared to defend your choice.

3. Identify any terms in the hypothesis that should be operationally defined--any terms for quantities used in the hypothesis which the investigator would need to know how to detect and/or measure.

4. Outline a procedure suitable for testing the hypothesis.

EXERCISE: FORMULATING HYPOTHESES

For each of the problems described below, generate a hypothesis suitable for testing under controlled conditions. The problems are intentionally broad in scope so several alternative hypotheses might be formulated for testing. You are to suggest one such hypothesis for each problem, not all possible hypotheses. Keep in mind that a hypothesis for experimenting is a simple, unambiguous statement of the relationship between a manipulated and a responding variable that provides direction for data gathering to decide if the hypothesis is falsifiable.

Problem 1.

Jane's puppy and Sam's puppy came from the same litter, yet one puppy grew much more rapidly than the other. Jane and Sam want to know what might have caused the difference in rate of growth.

Problem 2.

The teachers at Broadview Elementary School want to know if a sustained silent reading program will improve their pupils' abilities to read.

Problem 3.

The children in Mrs. Shaw's classroom have been reading about Galileo's experiments with objects rolled down inclined planes. They wonder what factors affect the speed of the objects as they roll off the incline.

Problem 4.

The 5th grade class at Drew Elementary School has been studying about environmental pollution. They were surprised to learn that detergents are polluting our nation's water supply. They decided to test the effects of detergents on living plants.

Problem 5.

A teacher and her class noticed that the crickets in the terrarium chirped more sometimes than others. They want to determine the cause.

Problem 6.

After a classroom mouse gave birth to babies, the children became curious as to whether mice could recognize their kin.

Problem 7.

A class was involved in studying a unit on solutions. The children became interested in the factors that affect the dissolving rate of solids.

Teaching Aid 2

ACTIVITY 5: OPERATIONALLY DEFINING

Through this activity the participants will develop a better understanding of 1) what operational definitions are and 2) the question-answering advantages that operational definitions have over conventional methods of general descriptions of terms.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader's behaviors in summary form are as follows:

1. Involve participants in examining variations in the meaning of the term "work."
2. Explain how scientists operationally define terms, such as "work."
3. Involve participants in measuring the amount of work done in moving an object.
4. Share some ideas that are important considerations in operationally defining.
5. Involve participants in an exercise to develop skill in identifying operational definitions.
6. Engage participants in an activity requiring the formation of an operational definition.

MATERIALS LIST

For each group of 4 participants:

1 wooden block (2" x 4" x 6")
1 cup hook
1 spring scale (5 Newton capacity)
1 meter stick
4 copies of Teaching Aid 2, More Work
1 flashlight battery (1½ volt)
1 bulb socket
1 bulb
2 large paper clips
1 baggie of assorted small objects (wooden, paper, plastic, metal and glass)
1 tray

For use by the workshop leader:

1 transparency of Teaching Aid 1
1 transparency of Teaching Aid 3
1 roll masking tape

ADVANCE PREPARATION

Prepare transparencies. Make copies of Teaching Aids 2 and 4 sufficient for the number of participants. Using masking tape, fasten a large paper clip to each end of each flashlight battery. Arrange materials for quick, orderly distribution to participants.

Review the teaching sequence and refine skills in operationally defining.

TEACHING SEQUENCE

1. Using a transparency of Teaching Aid 1, The Meaning of Work, have the participants examine the sentences using the word "work," and briefly discuss the many variations in the meaning of the term.

2. Explain that one of the primary reasons for the success of scientists compared with that of investigators in other fields has been their insistence upon providing operational definitions for the terms they use, while the average person is satisfied with basically meaningless general descriptions of quantities like time, motion, work, and energy. Many things that scientists study, like work, are just not easy to explain with words.

   Scientists have found an easy way to describe things like work. They simply ask themselves two questions:

   Q_1 How could I tell if I have some of this?

   Q_2 How could I tell how much of it I have? (Sometimes this question can't be answered.)

   The answers to these questions will give us an operational definition for work.

   The first question can be answered by describing what to observe.

   A_1 Work is done when an applied force moves an object.

   The second question can be answered by explaining "what you do" or "what operation you perform" to measure the amount of work. The following answer is offered for the simplist cases, where the force is constant and the motion takes place in a straight line in the direction of the force.

   A_2 To find the work done, attach a spring scale to the object and measure the constant force applied to move the object in newtons. Next, measure the distance the object was moved in a straight line path in meters, using a meter stick or metric tape. Find the product of force X distance and express this quantity as a newton.meter ($W = f \times d$).

   Now that the term "work" has been operationally defined, you should be able to solve problems dealing with work done.

3. Organize the participants in small groups of 4-5. Make available in an accessible location the materials listed for the Exercise: More Work (Teaching Aid 2). Allow about 10 minutes for participants to complete this activity. Involve the groups in comparing results. The questions at the end of the exercise should help the participants understand that the amount of work done is independent of the method of accomplishment. If a body does not move, even though a force is applied, no work is done. If you push against an immovable wall with all your strength, you are doing no work.

4. Using a transparency of Important Ideas About Operational Definitions (Teaching Aid 3), point out several important ideas to keep in mind when teaching operational definitions. Encourage participants to think of others.

5. Distribute copies of the exercise, Identifying Operational Definitions (Teaching Aid 4). Allow about 10 minutes for each participant to complete the exercise. Call on different participants to share their choice of the better operational definition for each word and defend their choice. The better choices are as follows:

   oxygen (b)
   pressure (a)
   small calorie (b)
   newton (b)
   ice (b)

6. Again organize the participants in small groups of 4-5. Distribute to each group a tray containing the following objects: a dry cell with paper clips attached, a bulb socket, a bulb, 2 pieces of insulated wire, and a baggie of assorted objects for testing as conductors. Instruct the participants to arrange the objects in such a way that the bulb lights. Ask, "What is the term used to refer to a system such as the one that you have constructed with the wire, cell, socket, and bulb?" (closed circuit). Now assign the participants the task of operationally defining the term "closed circuit." (An acceptable definition is as follows: "A closed circuit consists of two wires, a bulb, a socket, and a cell which are arranged in such a way that the bulb lights." What is done (the operation) is that the parts are arranged; what is observed is that the lamp lights.)

   Now have the participants disconnect one wire from the bulb socket so the bulb no longer lights. Ask, "What kind of system is this?" (open circuit). Have them operationally define open circuit.

   Next have them insert various objects from their baggie in the space between the detached wire and socket and determine which can be used to close the circuit. Call the objects that close the circuit "conductors" and the objects which do not close the circuit "non-conductors." These two words should also be operationally defined. An acceptable definition for a conductor based upon what was done and what was observed is:

A wire is removed from an arrangement of a cell, wire, and light bulb in which the bulb is glowing, and the light bulb goes out; if an object is used to replace the wire and the light goes on again, the object is a conductor of electricity.

Additional wires, cells, sockets, and bulbs could be supplied to construct and define series and parallel circuits. Acceptable definitions are:

Series Circuit: Any number of lamps, a cell, and wires connected so that all lamps glow when the circuit is closed. If any one lamp is unscrewed, all the lamps go out.

Parallel Circuit: Any number of lamps, a cell, and wires connected so that all the lamps glow when the circuit is closed. If any one lamp is unscrewed, the other lamps still glow.

REFERENCES

Commission on Science Education of the American Association For The Advancement of Science, Science - A Process Approach Commentary For Teachers, Xerox Corporation, 1970.

Intermediate Science Curriculum Study, Probing The Natural World, Volume 1, Morristown: Silver Burdett Company, 1970.

OVERWORKED

EXAMINE THE FOLLOWING SENTENCES FOR VARIATIONS IN THE MEANING OF THE WORD "WORK."

1. The day's work began at 7:30 a.m.
2. The machine doesn't work.
3. Not all metals work easily.
4. Work the butter and sugar before adding the eggs.
5. He had the works, from appetizer to dessert.
6. You are saved by faith rather than works.
7. The gears work against each other.
8. I can't work miracles.
9. You must work your contacts to get ahead.
10. Work your way through the obstacles slowly.
11. The grape juice is beginning to work.
12. Work her over and she will change her mind.

Topic 3 /Activity 5
Teaching Aid 1
(Transparency)

EXERCISE: MORE WORK

Question: Which requires more work--lifting a block of wood a distance of one meter or pulling a block of wood along a smooth horizontal surface for a distance of two meters?

MATERIALS LIST:

For each group of 4 participants:

1 wooden block
1 cup hook
1 spring scale (5 newton capacity)
1 meter stick

DIRECTIONS:

1. Find the center point on one end of the wooden block and screw the cup hook into the block securely at that point.

2. Attach the spring scale to the cup hook. Using a constant force, slowly lift the block of wood for a height of one meter. Record measurements in the table below.

3. Now locate a smooth table or other horizontal surface. Using a constant force, slowly pull the block along the surface for a distance of two meters. Record measurements.

4. Calculate the work done to lift the block and to move the block along the horizontal surface.

5. Which took more force--lifting the block or pulling the block along the table? Which required more work?

Table I
Work Done In Lifting The Wooden Block

Direction of Force	Force (newtons)	Distance (meters)	Work Done f x d (newton.meters)
Upward ↑			
Horizontal →			

Teaching Aid 2

6. Answer the following questions:

   - Suppose John and Keith lifted the block of wood ten times to the height of one meter. John did the job in five minutes. Keith took ten minutes. Who did more work?

   - Suppose John was strong and muscular. Keith was sickly and weak. What effect would this have on how much work they did in lifting the block?

   - Suppose Keith used an inclined plane to lift his block while John lifted his block directly. Would this affect the amount of work done?

   - Suppose John and Keith tried to lift a very heavy rock. They pulled and tugged for 15 minutes, but were unable to move the rock. How much work was done?

IMPORTANT IDEAS ABOUT OPERATIONAL DEFINITIONS

- The definition is needed because of lack of agreement, or ambiguity in the meaning of a term.
- The definition is based on observable properties or operations which can be performed by the person using the definition.
- The definition describes what you are to observe and perform.
- There may be more than one operational definition of a term.
- One definition may be more adequate or useful than another, depending upon the situation in which the definition is used.

Teaching Aid 3

EXERCISE: IDENTIFYING OPERATIONAL DEFINITIONS

I. Directions: Two definitions are given for a series of terms. Choose which is the better operational definition, and be prepared to defend your choice. The better definition will clearly state what you observe and what you perform (the operation).

Oxygen:

a) An element composed of atoms having atomic number 8 and atomic weight 16.
b) A gas that causes a glowing splint to burst into flame when the splint is placed in a container of the gas.

Pressure:

a) Measure the total force and divide the measurement by the measurement of the area on which the force is applied. The quotient is a measure of the pressure.
b) How hard something is pressing.

Small calorie:

a) A unit of heat.
b) The amount of heat that increases the temperature of 1 milliliter of water 1°C.

Newton:

a) A unit of force in the metric system.
b) The force required to give a one-kilogram mass an acceleration of one meter per second.

Ice:

a) A solid made up of a three-dimensional network of water molecules.
b) A solid that changes to a liquid at 0°C.

II. Directions: In each of the following statements, identify the words for which there is need of an operational definition.

A. A flower is a group of specialized leaves.
B. Metals carry electricity better than nonmetals.
C. Matter is anything that takes up space and has weight.

III. An operational definition of an insect is, "An insect is an animal with six legs and a body that is divided into three main parts."

From the information given in each of the following descriptions, write whether the animal is an insect or not, or whether the information is insufficient.

- This animal breathes with gills, has a body divided into three parts, and has eight legs. ____________________
- This animal has six legs, two wings, and a three-part body. ____________________
- This animal has four wings and a body divided into three parts. ____________________
- This animal has six legs that are jointed, a three-part body, no wings, and a hard outer covering. ____________________

ACTIVITY 6: ORGANIZING AND INTERPRETING DATA: KEY NUMBERS

Interpreting data is a skill that can be transferred to a variety of experiences in and out of school. The ability to interpret data, while essential in science, is also vital in other disciplines. School textbooks typically include charts, graphs, diagrams, photographs, and other types of illustrative material as aids in communicating ideas or to present data for interpreting; however, it is not unusual for students to totally ignore these instructional helps and rely entirely upon the narrative content. From the administration of standardized tests in Mississippi schools, skill in interpreting data has been identified as an area of poor test performance in many school districts.

Since everyone constantly encounters situations throughout their lives requiring interpretation of data, more attention needs to be focused on the development of this skill at every level in the educational system. Probably the best approach in developing this skill is to use practical problem solving situations requiring students to collect, organize, and interpret data.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Introduce the activity with a problem involving collection of data.
2. Organize participants for data collection.
3. Illustrate the use of key numbers in treating data.
4. Discuss most appropriate key number for problem situation.
5. Involve participants in making a histogram of data.
6. Guide participants through practice exercises to develop skill in techniques introduced.

MATERIALS LIST

For each group of 4 participants:

1 metric measuring tape
8 sheets of graph paper
4 copies of Practice Exercise: Histogram, Teaching Aid 3

For large group instruction:

1 transparency of Teaching Aid 1
1 transparency of Teaching Aid 2

ADVANCE PREPARATION

Prepare copies of transparencies and the practice exercise. Make sure an adequate quantity of graph paper is available.

TEACHING SEQUENCE

1. Introduce the activity using the following description of a situation or a similar type problem which you have devised:

   Suppose you have a problem which requires, as most problems do, collecting data to solve the problem. The data you need turns out to be a bunch of numbers. Numbers can be confusing, especially when you have a lot of them. You then have to organize or treat the data in some way to make sense of the numbers. Take, for example, the problem of finding the best height to hang posters in an advertising campaign of a product being marketed for women. What data would you need to collect? (Participants should suggest the eye-level heights of a large sample of women.) How large a sample would you need to measure? (The size of the sample would depend on several factors, such as the size of the total population to whom the campaign was directed, the degree of accuracy desired, the cost of obtaining the data, and the time required to collect and process the data.)

   If the problem were narrowed to determining the eye-level height best for hanging advertising posters for participants in this workshop, what data would we need to collect? How could we obtain the data? How accurate would we need to make the measurements?

2. Organize the participants in groups and make available metric measuring tapes for data collection according to their plans. Have the participants record the eye-level heights on the chalkboard. The unorganized array of numbers should illustrate how confusing a bunch of numbers can be. Some measurements will probably be to the nearest whole centimeter, while others may report fractional parts. (If possible, obtain eye-level heights of more than 20 people.)

3. Use the data to illustrate different techniques for treating the data. Begin by rounding the numbers to the nearest whole centimeter and organizing the numbers from smallest to largest measurement. Explain that there are four different key numbers which tell us something about the data. Define each key number and illustrate how to find each key number with the data they collected.

   Key Numbers:

   Mode: The number or thing that is listed the most times in a set of data is the mode. To find the mode examine the ordered sequence of numbers and locate the most frequently occurring number. The data may be bimodal--have two numbers occurring with equally high frequency.

   Median: The middle number in a set of data that has been put in order from smallest to largest is the median. There are just as many numbers smaller than the median as there are numbers larger than the median. The crossing off method for finding the median works well with children. Show participants how to find the median by crossing off as many numbers from one end as from the other end in their array of data organized from the smallest to the largest number.

Example 1. Odd number in distribution

~~65~~, ~~65~~, ~~66~~, ~~67~~, ~~67~~, 68, ~~69~~, ~~69~~, ~~70~~, ~~71~~, ~~72~~
↑
Median

Example 2. Even number in distribution

~~65~~, ~~65~~, ~~66~~, ~~67~~, ~~67~~, ~~68~~, ~~69~~, ~~69~~, ~~70~~, ~~71~~
↑
Median
(67.5)

Mean: The mean is usually called the average in elementary school. The mean of any distribution is the sum of the numbers divided by the count of how many numbers (n). Have several participants sum the numbers and divide by n to find the mean. (Calculators may be used.)

Range: The range is the difference between the largest and smallest numbers in a set of data. The range shows how much the data changes or varies. When you find the range for a whole set of data, you find the Full Range. Sometimes, you may want to use only the numbers in the middle half of the data. Then, you find the range of the middle half of the data. That is the Middle Range. Illustrate finding the range with the data that participants have collected.

Example 1. Full Range
Subtract the smallest number in the data from the largest.

65, 65, 66, 67, 67, 68, 69, 69, 70, 71, 72

72 - 65 = 7 Full Range

Example 2. Middle Range
Count the pieces of data and divide by 4. Cross off that many pieces of data from each end of the ordered sequence of numbers. When you have a fractional answer like 2 3/4 or 7 1/2, round it off to the next smaller whole number. (One-fourth of the data crossed off from each end (1/4 + 1/4 = 2/4 = 1/2) leaves the middle half of the data. Rounding fractional answers down assures that 50%+ of the data is included in the middle range.)

~~65~~, ~~65~~, 66, 67, 67, 68, 69, 69, 70, ~~71~~, ~~72~~

n = 11 numbers

11 ÷ 4 = 2 3/4

Middle Range = 70 - 66 = 4

4. Discuss the appropriateness of each of the key numbers for making a decision about the height for hanging the posters. (Help the participants to understand that selecting the appropriate treatment of the data for solving a problem is dependent upon the type problem being solved, the amount and kind of data available and many other factors; therefore, it is impossible to describe exact procedures to follow. For this reason, data interpretation is a powerful mechanism for developing students' thinking skills.) A transparency of Teaching Aid 1, Choosing Among Mean, Median, and Mode, might be used to focus discussion.

   In their discussion, participants should be led to conclude:

   - The mode would not be useful in deciding the height to hang the posters. The mode would not be a number that would represent the total population very well.
   - The median height could well be the best level to hang the posters. At that height the posters would neither be too high nor too low for most of the population sampled.
   - The mean is the single best value with which to make predictions about the population. However, a few extremely short or extremely tall people in a small sample may tend to skew the mean toward one end of the data. If this is the case, the median would be a better number than the mean to use in deciding the best height to hang the posters.
   - The full range would reveal the variability in the sample but would not be particularly useful in deciding where to hang posters. If the posters are to be centered at the median eye-level height, it would be helpful to know if the number of centimeters of poster on either side of the median was within the full range.
   - The middle range is useful in making a prediction that has a 50% chance of being right but would not be useful in deciding the single best height for hanging posters.

5. Explain that graphing data is another useful way of treating a confusing array of numbers. There are many different types of graphs. One of the most useful when you have lots of measurements or number counts from many different people is the histogram. A histogram will help to reveal any patterns in the data. Distribute graph paper to the participants. Instruct them to refer to Appendix B of their manual and use the "How To" Make A Histogram booklet as a

reference in preparing a histogram of the data they collected. After they have completed their histograms, demonstrate the procedures for finding the mode and median using transparencies of Teaching Aid 2. Then, have them find the mode and median for the data in their histogram.

6. Provide additional graph paper and copies of Practice Exercise: Histogram (Teaching Aid 3). Allow adequate time for participants to develop proficiency in these basic skills. Collect or supply additional data as needed for practice.

   Data collected might include:

   - Mileage distance traveled by each participant to the workshop.
   - Pulse rate of each participant.
   - The number of members in each participants' family.

Choosing Among Mean, Median and Mode

THE MODE

Advantages

Gives the item occurring most often

Easy to read from a frequency table or graph

Disadvantages

Might not be near center of the values

Might be more than one mode

Might change drastically with the addition of new scores

Might not exist

Topic 3/Activity 6
Teaching Aid 1
(Transparency)

THE MEDIAN

Advantages

Gives the middle score

(half are at or above the median;

half are at or below the median)

Not as easily influenced by extreme scores

(see Median vs. Mean)

Disadvantages

Does not give information about the total of the scores

Requires that the scores be ordered

Might not be a member of the set

Topic 3/Activity 6
Teaching Aid 1, Cont.
(Transparency)

THE MEAN

Advantages

Is the most common meaning of the word "average"

Can often be computed quickly by calculator

Gives information about the total of the scores

Is the most useful number in most statistical work

Disadvantages

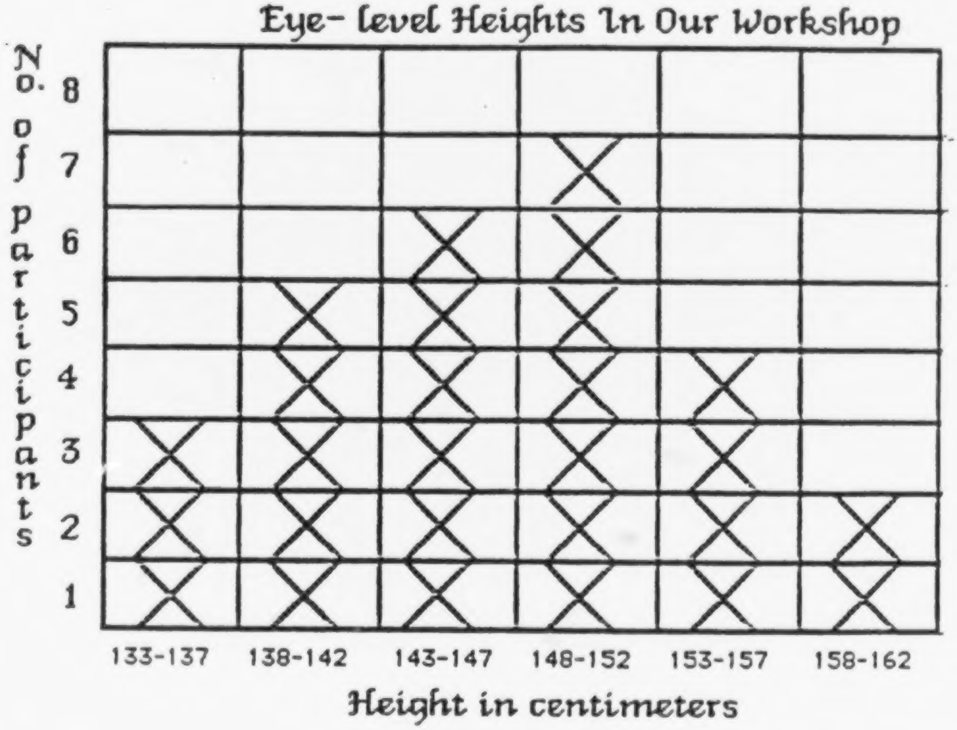
Might be greatly influenced by extreme scores

Might not be a member of the set

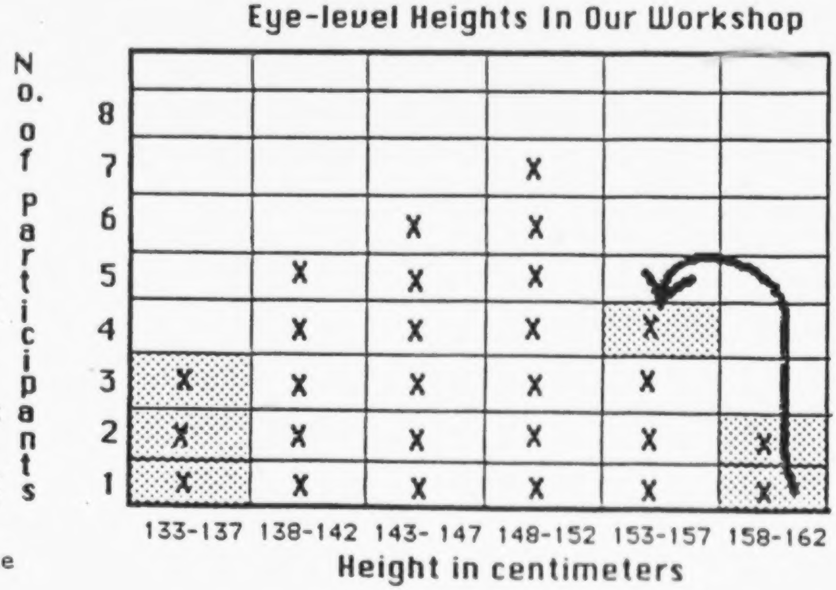
Statistics and Information Organization, Creative Publications, Inc.,
P. O. Box 10328, Palo Alto, CA 94303, Preliminary edition, 1977
(Developed at University of Oregon with funding from the National
Science Foundation, Grant No. SED74-15047).

Topic 3/Activity 6
Teaching Aid 1, Cont.
(Transparency)

Using a histogram to find the median and the mode.

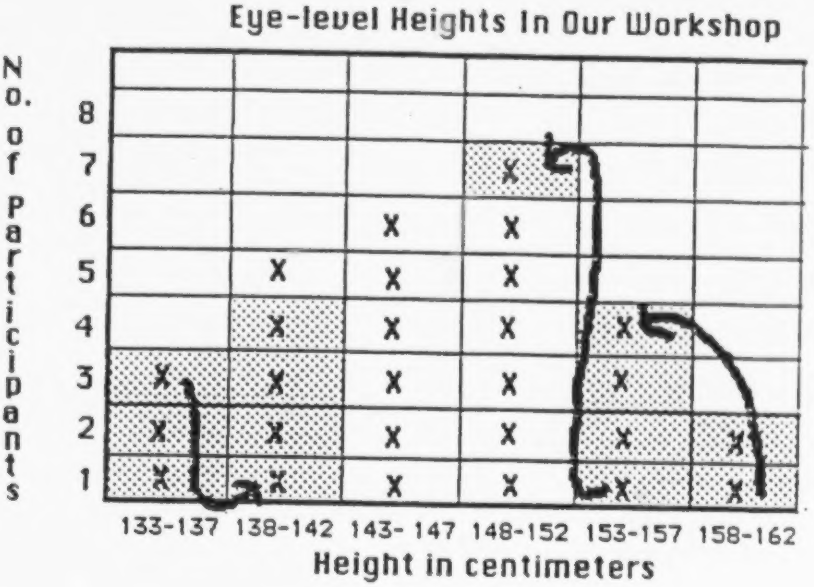


To find the median, start crossing off X's on the histogram. Cross off the same number of X's from each end, but cross off the X's on the lower end starting at the bottom of each column, and cross off the X's on the higher end starting at the top of each column. When three X's are crossed off from each end, the histogram looks like this.

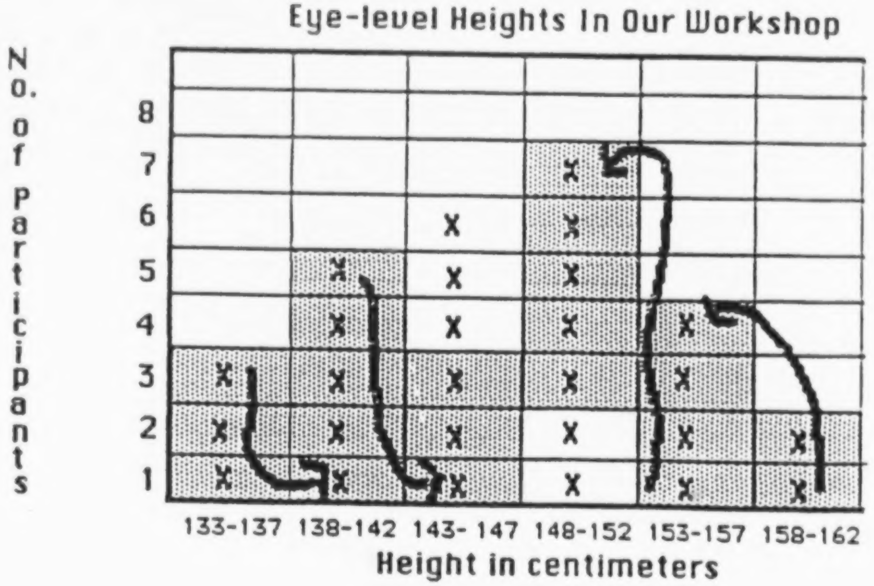


Topic 3/Activity 6
Teaching Aid 2
(Transparency)

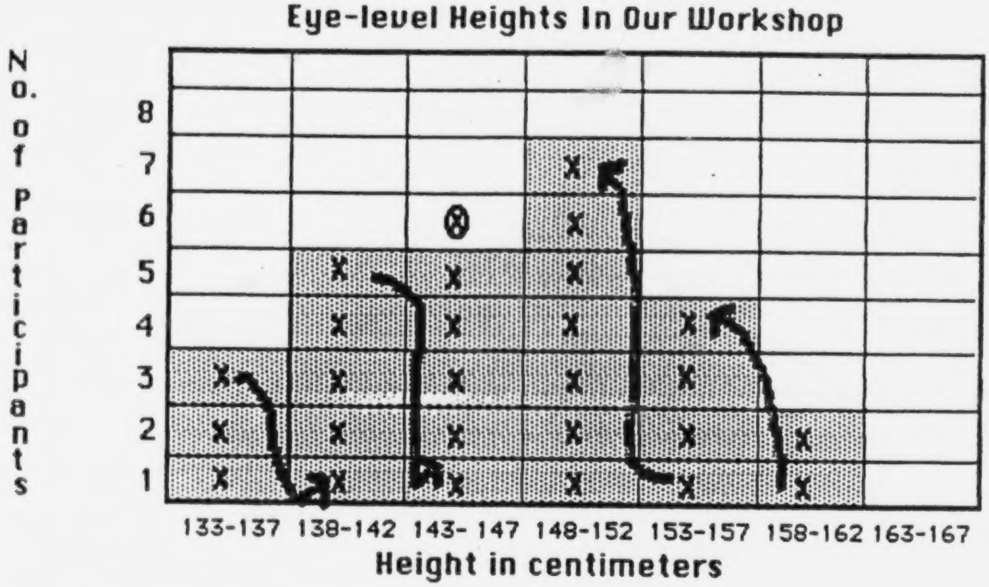
When seven X's are crossed from each end, the histogram looks like this.



When eleven X's are crossed off from each end, the histogram looks like this.



Topic 3/Activity 6
Teaching Aid 2, Cont.
(Transparency)



Cross off two more X's from each end. That leaves one X. This is the MEDIAN.
Place a circle around this X. ⊗ The median is from 143-147 cm.

REMEMBER THE RULES OF
GOOD GRAPHING !!!!!

PRACTICE EXERCISE: HISTOGRAM

1. The lower-grade teachers in a school found that the younger children often became confused trying to find the school library. A group of thirty first-graders were timed from a starting point in the hallway near the first grade classroom. A list of the times is presented below.

60, 75, 62, 78, 80, 50, 100, 110, 106, 55, 80, 70, 72, 73, 58, 95,
61, 70, 74, 85, 83, 104, 78, 88, 59, 108, 70, 80, 90

a. Prepare a histogram for the data.
b. Find the mode.
c. Find the median using the crossing off method on the histogram.

2. The ages of a group of junior high school science teachers who attended a summer workshop at the University of Southern Mississippi are shown below.

50, 33, 24, 40, 32, 42, 32, 31, 32, 55, 40, 40, 43, 31, 28, 36, 30, 39, 37, 27, 35, 35, 40, 46, 25, 28, 43, 49, 47, 40, 41, 38, 38, 54, 39, 24, 36, 30, 49, 59

a. Prepare a histogram for the data.
b. Find the mode.
c. Find the median using the crossing off method on the histogram.

ACTIVITY 7: CONSTRUCTING AND INTERPRETING GRAPHS

The basic purpose of a graph is to relate two or more measurements. Since experimenting involves manipulating one variable while measuring the effect of the change on another variable, two sets of measurement need to be compared. Graphs are commonly used by scientists to determine if any pattern or relationship exists between the independent and dependent variable. This activity involves the participants in collecting data, constructing appropriate types of graphs for the data, and interpreting the data.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Point out written resources to be used in preparing graphs and explain importance of graphs in treating data.

2. Organize participants in groups and give directions for collecting data on interacting water systems.

3. Involve participants in self-check of their graphs.

4. Using a questioning sequence, guide participants in the interpretation of the graph showing temperature changes in the interacting water systems.

MATERIALS LIST

For each group of 4 participants:

1 small can (tomato paste or small juice can)
1 styrofoam cup (large enough to insert the small can and surround with 200 ml of water)
2 thermometers
2 plastic spoons
4 graph paper sheets
4 copies of Exercise Sheet: Interacting Water Systems (Teaching Aid 1)

For the large group to use as needed:

1 large container of warm water (35°C)
1 large container of crushed ice
1 clock with second hand

TEACHING SEQUENCE

1. Have the participants locate the 'How To' booklets, "Make a Line Graph" and "Use Graphs To Compare Two Sets of Data" in Appendix B of their manual. Tell them that the booklets were written for children in the intermediate grades to develop their skills in constructing and interpreting graphs. The booklets will be used as references in constructing and interpreting graphs for data collected in this session. Suggest that if their experience with graphing has been limited, they

may wish to work through the booklet, "Make a Line Graph" before beginning the activities for this session.

Explain that the basic purpose of a line graph is to relate two or more measurements. Since experimenting involves manipulating one variable while measuring the effect of the change on another variable, two sets of measurements are compared. Graphs are commonly used by scientists to determine if any pattern or relationship exists between the two variables (independent and dependent) in an experiment.

2. Organize the participants in groups of 4 for the data collection activities. Remember to allow each group to work at their own pace since participants will differ significantly in skill with graphing. In the first activity the participants will observe and record the temperature changes taking place over time when two samples of water, one an ice-water mixture and the other warm water, in separate containers interact through a container wall, without being mixed. Directions for the activity are described on Exercise Sheet: Interacting Water Systems (Teaching Aid 1). Point out the location of all materials needed for the activity. Move about the room and assist groups as your help is needed.

3. As groups complete the activity, meet with them separately or with several groups at a time to self-check their graphs for the following details:

   - Each axis labelled and measurement unit indicated.
   - The independent variable (time) on the horizontal axis and the dependent variable (temperature) on the vertical axis.
   - Numbers written along the lines and not in the spaces.
   - Equally spaced interval along the scale on each axis.
   - Title for the graph.
   - Points correctly plotted.
   - Line of best fit showing any pattern in the data.
   - Each line appropriately labelled or coded.

4. Use the following questioning sequence to guide participants in interpreting the data:

   1. How does the temperature change in the warm water compare to the temperature change in the ice-water mixture as time elapsed? (Steady decline in warm water temperature compared to no change in ice-water mixture for several minutes. Then slow increase in temperature of ice-water mixture until both systems reached same temperature).

2. What was the direction of heat transfer in the interacting water systems? (from warm water to ice-water mixture)

3. What evidence from the graph supports your answer? (The warm water steadily declined in temperature indicating a loss of heat energy.)

4. How do you explain the relatively constant temperature of the ice-water mixture for several minutes in contrast to the decline of the warm water temperature? (The heat energy, steadily transferred from the warm water (higher energy state), went into melting the ice, thus breaking the attractive forces holding the water molecules in the solid state. Therefore, no increase in temperature occurred in the ice-water mixture until all the ice melted. This answer may not be given by participants at this point. If not, the next two questions will guide their thinking toward the formulation of an answer.)

5. Since the temperature of the ice-water mixture did not rise for several minutes, what happened to the heat energy lost by the warm water? (They may give several different answers, such as: It went into the air. It was used to heat the metal can. Ask, "Which is a better conductor of heat energy: a metal can, air, or a styrofoam container?" Try with probing to get participants to realize that most of the heat energy must have been transferred through the metal can to the ice-water mixture. The next three questions may help.)

6. From your graph can you determine how long in minutes it took the ice to melt? (the number of minutes shown as a plateau on the line showing temperature change in the ice-water mixture)

7. How is the solid state of matter different from the liquid state? (In solid state the particles are held rigidly in place. In the liquid state particles are free to move in relationship to each other. The liquid state is a higher energy state characterized by more rapidly moving molecules.)

8. How can a solid be changed to a liquid? or What is needed to change a solid to a liquid? (Energy must be put into a solid system to change it into a liquid system.)

9. What was the energy source and what was the energy receiver in these interacting systems? (Warm water was the energy source and the ice-water mixture the energy receiver.)

10. After the ice melted, what happened to the temperature of the water inside the can? (Temperature increased until it reached the same temperature as water outside the can.)

11. How many minutes did it take for the warm water temperature to reach 30°C? (require interpolation from their graphs)

12. If you examined the temperature of the water in each container five minutes from now, what would you expect the temperature in each container to be? (require extrapolation of the line on the graph)

13. Summarize what the graph reveals about the interaction of the warm water system with the ice-water system.

(Data collected and interpreted through experimenting should teach science content as exemplified by the questioning sequence.)

EXERCISE SHEET: INTERACTING WATER SYSTEMS

In this exercise you will be observing and recording the temperature changes taking place when two samples of water in separate containers interact through a container wall, without being mixed. The data collected will be used in constructing a graph.

You will need:

1 small metal can
1 large styrofoam cup
2 thermometers
2 plastic spoons
100 ml of crushed ice-water mixture
200 ml of warm water (35°C)

DIRECTIONS:

Place 100 milliliters of crushed ice-water mixture in a small metal can. Pour 200 milliliters of warm water (35°C) in the styrofoam cup. Insert a thermometer and plastic spoon in each container. Stir the contents of each container and take an initial temperature reading. Do not remove the thermometer or spoon. Now insert the small can containing the ice-water mixture into the cup of warm water. Constantly stir each container to maintain equal distribution of heat energy within the water systems and record the temperature of each system every half minute. (Be very careful with the thermometers. Do not allow the cups to tip over breaking the thermometers. Mercury vapor exposure from broken thermometers is a health hazard.) The moment all the ice in the can has melted, indicate the number of minutes on your record sheet. Continue recording the temperature of each system for five minutes after the ice has melted.

Teaching Aid 1

Data Table

Time (min.)	Temperature °C	
	ice water	warm water
0		
½		
1		
1½		
2		
2½		
3		
3½		
4		
4½		
5		
5½		
6		
6½		
7		
7½		
8		
8½		

Teaching Aid 1, Cont.

TOPIC 4: TEACHER QUESTIONING TECHNIQUES

Iva D. Brown
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As long ago as 1912, Romiet Stevens,[1] in a study of questioning behavior by teachers, decried the high rate of questioning by teachers and the low level of thought demanded. Numerous studies since that time have substantiated her findings that most of the questions in classrooms require simple recall and rarely require the higher level cognitive processes of application, analysis, synthesis, and evaluation. Despite recognition since the time of Socrates of how powerful an instructional tool questioning can be in guiding the learner to more advanced levels of cognition, low-level questioning, which in many instances emphasizes trivia, still seems to dominate in classrooms.

Mary Budd Rowe,[2] who has contributed significantly in recent years to the body of research on questioning, reported that questions are used by the teacher for essentially three purposes:

> (1) evaluation, in which the teacher tries to find out what the student already knows or remembers; (2) control, in which the teacher carries on a kind of inquisition whose implicit function seems to be to reduce the need for overt disciplinary moves; and (3) instruction, in which the teacher uses questions to point children to resources, to point out discrepancies, and, in other ways, to produce some level of cognitive conflict.

William D. Floyd[3] in his research found that questions seemed to be used more for evaluation than for instruction. Teachers seemed to use questions to check up on what a student knows, rather than on how he thinks about what he knows.

In preparing these instructional materials, the two basic hypotheses offered by Norris M. Sanders[4] in his book Classroom Questions: What Kinds? have been accepted. Sanders' hypotheses were:

> First, teachers can lead students into all kinds of thinking through careful use of questions, problems, and projects. Second, some teachers intuitively ask questions of high quality; but far too many over-emphasize those that require students only to remember; and practically no teachers make full use of all worthwhile kinds of questions.

Topic 4

The key to successful classroom experiences with hands-on science activities is clearly the use of questioning in the instructional process. Without well-thought out questions in the lesson, manipulative activities may soon deteriorate into rather meaningless messing around.

The instructional sequence for this topic will begin by engaging teachers in examining some fundamental guidelines for promoting maximum learning through questioning, which have been compiled from research and authoritative opinion. However, the major thrust will be to develop the teachers' skill in formulating an ordered sequence of questions to stimulate and guide students' thinking processes as they are involved in a concrete manipulative experience.

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[1] Romiet Stevens. The Question as a Measure of Efficiency in Instruction, Contribution to Education, No. 48, Teachers College Press, Columbia University, New York, 1921.

[2] Mary Budd Rowe. Teaching Science as Continuous Inquiry. New York: McGraw-Hill Book Company. 1973. pp. 337-338.

[3] William D. Floyd. "An Analysis of the Oral Questioning Activity in Selected Colorado Classrooms," Unpublished Ed.D. Dissertation. Colorado State College, Greeley, 1960.

[4] Norris M. Sanders. Classroom Questions: What Kinds? New York: Harper & Row, 1966, pp. 1-2.

ACTIVITY 1: SPECIFIC TECHNIQUES FOR IMPROVING YOUR QUESTIONING SKILLS

This activity should aid elementary teachers in examining the role of questioning in their science program. Specific suggestions compiled from multiple references related to improving questioning techniques are briefly summarized. Many of the suggestions are based upon extensive research; others are practices educators believe to be sound out of their experiences. Changing questioning behavior requires first a knowledge of effective and ineffective behavior patterns and second arduous effort on the part of the individual teacher to modify any counterproductive behaviors. This activity is limited to developing the knowledge base. The follow through with the second step must be planned and executed at the local level with teachers supporting and encouraging each other.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader's behaviors in summary form are as follows:

1. Introduce the topic by examining how questioning is used in classroom instruction.
2. Using the prepared teaching aids, lead a discussion related to effective and ineffective questioning techniques.
3. Analyze a video-cassette tape and a transcription of an audio-tape, illustrating effective and ineffective questioning techniques.
4. Plan with teachers a mechanism for working toward improvement in questioning techniques with the support and assistance of fellow teachers.

MATERIALS LIST

For each participant:

Teaching Aid 2, Keys to Effective Questicning
Teaching Aid 3, Suggestions For Better Questioning
Teaching Aid 4, A Transcription of a Classroom Audio Tape

For the workshop leader:

T.V. cassette player and T.V. monitor
Video-cassette tape - segment of the film "Dont't Tell Me I'll Find Out," SCIS Curriculum project
Transparency of Teaching Aid 1
Questions: The "Stock in Trade" of Teachers
Overhead projector

ADVANCE PREPARATION

Prepare a transparency from Teaching Aid 1, Questions: The "Stock in Trade" of Teachers. Make copies of Teaching Aids 2, 3 and 4 for each participant. If possible, distribute as handouts several days before the workshop session Teaching Aids 2 and 3 to be studied in advance.

TEACHING SEQUENCE

1. To introduce the topic, display the transparency prepared from Teaching Aid 1, Questions: The "Stock in Trade" of Teachers, which points out how questioning dominates classroom teaching behavior. Solicit from the participants a listing of ways that questioning is used in the classroom. Redirect the question until a reasonable listing has been obtained. The list might include:

    - Arouse interest and motivate to participate in the lesson
    - Assess prerequisite knowledge before beginning an instructional sequence
    - Obtain information necessary to the problem being explored
    - Guide thinking processes
    - Focus an inattentive student's attention
    - Discipline a disruptive student
    - Diagnose students' strengths and weaknesses
    - Help students to see applications or relationships
    - Review and/or summarize content
    - Check comprehension
    - Evaluate learning outcomes

2. If Teaching Aid 2, Keys To Effective Questioning and 3, Suggestions For Better Questioning, were made available prior to the session, lead a discussion modeling strategies recommended in the handouts. Carefully plan the questions to be used in leading the discussion. If the teaching aids weren't made available in advance, distribute these to participants and review each. Encourage discussing and relating of the suggestions to experiences the teachers have had in their classrooms.

3. Make available a transcription of an audio-tape (Teaching Aid 4) and a videocassette tape for critical examination. The teachers may work in groups examining and discussing the effectiveness of various behaviors on the transcription and tape. Point out that no teacher would probably ever carry through even a short questioning sequence free from mistakes. Being cognizant of effective strategies and striving to improve is what should be emphasized. This exercise will give you the means to analyze your own behavior.

4. Encourage participants to use cassette recorders to tape classroom discussions. Examine the tapes for effective and ineffective patterns of behavior. Suggest that they work with a fellow teacher, if at all possible. It helps to have a second opinion. Explain that becoming aware of behaviors which may be counterproductive is the first step toward self-improvement. Correcting well entrenched behaviors takes time and concerted effort.

QUESTIONS: THE "STOCK IN TRADE" OF TEACHERS

TEACHERS SPEND AS MUCH OR MORE TIME ASKING QUESTIONS AS USING ANY OTHER KIND OF VERBAL UTTERANCE. STUDIES HAVE SHOWN THAT TEACHERS SPEND 70 OR 80 PER CENT OF THEIR TIME ASKING QUESTIONS. QUESTIONS HAVE ALWAYS BEEN THE 'STOCK IN TRADE' OF TEACHERS.

WHAT ARE SOME WAYS QUESTIONS ARE USED BY TEACHERS?

Topic 4/Activity 1
Teaching Aid 1
(Transparency)

KEYS TO EFFECTIVE QUESTIONING

1. Write down specific wording of 6-8 questions in your lesson plan before class. These questions should relate to the topic being explored and build toward the objectives of the lesson. Some of the questions should call for naming, identifying, and describing information. Other questions might clue students either to answers or to processes that could be used to find answers. Still other questions should be open-ended, prompting search for additional data or relationships or encouraging explanations. As the questions are formulated, keep in mind the cognitive development of the children and adjust your questions accordingly.

2. Ask your question as simply, concisely, and directly as possible. Ask your question before designating which child should answer. This keeps all the children listening. Pause briefly after asking the question so that all the children have time to think about the question. Ask an individual child to respond to your question. Total class shouting out of answers could result in classroom discipline problems for the teacher. Involve as many children as possible during the science lesson: volunteers and non-volunteers, slow and bright, etc. As a rule, rapid-fire questioning should be limited to obtaining specific facts essential to developing the lesson or in a review of content.

3. Allow wait-time after asking a question. There are two types of wait-times. Wait-time 1 is the initial wait-time when an instructor waits for the first response. Untrained teachers wait less than a second for wait-time 1. For students to become more involved in discovery, you need to increase your wait-time to at least three seconds. This gives the learner more opportunity to think, create, and demonstrate more fully their potential.

   Wait-time 2 is the total time a teacher waits for a class to respond to the same question. Wait-time 2 may involve several minutes, particularly if the question asked requires critical or creative thinking. Mary Budd Rowe believes wait-time 2 is more important for a teacher to develop. She found dramatic increases in student responses when teachers used it. Responses from the poorer academic students, furthermore, increased significantly with longer wait-time 2. Obviously, convergent questions aren't appropriate for multiple responses to the same question and wouldn't apply for wait-time 2.

   Wait-time is also important to the teacher in thinking through the questioning sequence to follow.

4. Listen carefully to student responses and respond appropriately. Give nonverbal signals to show you are concerned and that you are listening. If a student responds correctly, accept the response but do not overreact. Recent research indicates that rewarding students may, in fact, cause less student involvement and give some students unrealistic and

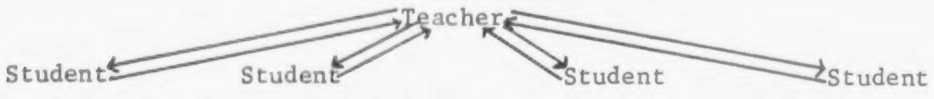
distorted impressions of their ability. Rewards aren't always undesirable and should be given when performance merits recognition. However, when praise is overused, students fall into patterns of mediocre performance. If a student gives a partially correct or incorrect response, use probing techniques to help the student build a more acceptable response. As a general rule, you should not move on to another student without giving the first student an opportunity to formulate a better response. These answers give you clues about misconceptions or errors in students' thinking which interfere with learning. A short questioning sequence might be all that is needed to overcome the problem.

5. Use more questions calculated to produce conceptual conflict. Socrates, that most famous of teachers, used questioning to place the learner first in a state of conflict. In the words of Piaget, the learner must first be in a mental state of disequilibrium, which leads to adaptation of the cognitive structures to reach a new higher level of equilibrium. According to Mary Budd Rowe, "Children, left unprompted, will usually tend to hop from system to system rather like grasshoppers, sampling the fare casually and moving on to a new leaf. Appropriately stated questions, challenges, and comparisons made by the teacher can reenergize their brains and feelings with respect to a particular system." Question stems, such as the following, are useful in stimulating thinking:

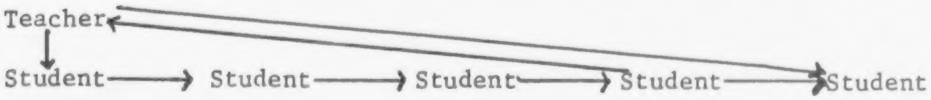
   - What will happen if ...
   - If this is so, then ...
   - What if you added or took something away from the ...
   - How would you ...
   - What is your supporting evidence ...
   - What other interpretations are possible ...
   - How can you account for it ...
   - Under what circumstances ...

6. Ask fewer questions. Make each question yield as much information as possible. The object should be to make the lesson a joint inquiry rather than an inquisition by the teacher. Make discussions more student centered and conversational.

Teacher Centered Discussion



Student Centered Discussion



7. _Evoke more complete and more complex responses_. Longer, better thought out answers begin to occur when wait-time is adequate. The effectiveness of any specific questioning strategy is never greater than the level of the pupil answer you accept. Ask questions which require more complex answers. Positively reinforce students for longer and better answers. Ask students who give short, incomplete answers to contribute more.

SUGGESTIONS FOR BETTER QUESTIONING

1. Check the wording of your questions to determine if you have made them broad or narrow.
2. Try to word your questions to avoid "yes/no" answers, unless that's what you really want.
3. Avoid repeating student responses.
4. Develop techniques for getting students to listen to and interact with each other.
5. Encourage your students to ask questions.
6. Encourage students to expand on their ideas.
7. Do not stop the discussion with the right answer.
8. Increase wait-time 1 and 2.
9. Do not give rewards during a discussion, which magnify the contribution of a particular student.
10. Avoid asking multiple questions.
11. Refrain from always providing an authoritative answer to every question.
12. Do not answer your own question.
13. Ask students to clarify material.
14. Avoid repeating your question.
15. Rephrase a question only after it has become apparent that it was misunderstood or vague.
16. Ask your question before designating which child should answer.
17. Call on volunteers as well as nonvolunteers.
18. Ask questions in a variety of ways.
19. Talk less and ask more.
20. Use good grammar.
21. Encourage student to student interaction.
22. Do not use questioning as a means of punishing a disruptive student.

TRANSCRIPTION OF CLASSROOM AUDIO-TAPES

Mrs. Smith's Lesson

Mrs. Smith, in this transcription, is teaching a second grade class a lesson from the Science Curriculum Improvement Study (SCIS) Unit, Interactions and Systems. The lesson involves the children in lowering a tea bag partially filled with copper chloride, a greenish-blue, granular chemical, into a container of water, so that the bottom of the tea bag is submerged to a depth of about one-half inch in the water. The top of the tea bag is folded over the edge of the container to hold the bag in place. The children are instructed to observe what happens. The activity, as designed for the SCIS curriculum, provides a concrete example of interaction to be observed and processed. Interaction occurs when objects do something to each other, thereby bringing about a change. The interaction that occurs in this activity involves the water diffusing into the tea bag, the copper chloride dissolving in the water, and the subsequent diffusion of the copper chloride solution through the tea bag into the surrounding water. The evidence for interaction is (1) the gradual change of the water color to blue-green, (2) the wavy pattern (schleiren) seen as the concentrated copper chloride solution mixes with less dense water, and (3) the crystals of copper chloride disappearing from the tea bag. The teacher in this lesson should, through questioning, guide the children as they observe and process the evidence related to the interaction.

(T - teacher, P - pupil)

1. (T) In the middle of your tray -- leave it (tea bag) on the paper towel. Take this little white bag with the blue stuff in it and set it inside this plastic thing. I'm just going to hold mine up to show you, so that the little blue stuff in the white bag will be touching this liquid. Just so that it will be just touching. Let it just touch that liquid.
2. (P) The bag?
3. (T) Yeah. Put the bag -- you have to fold it just a little. Then I want you to watch and see what happens.
4. (P) Mutter, exclaim -
5. (T) That's right. Watch it now. Just let me look ...
6. (P) (Talking excitedly all at once)
7. (T) Now pick it up and look at it without spilling it. Pick it up and hold it up to the light.
8. (P) Mine is turning green.
9. (P) The powder is turning green and the water is turning blue.
10. (T) What happened to it?
11. (P) My water turned blue.
12. (P) It changed to gray.
13. (P) It melted and turned blue.
14. (T) It melted?
15. (P) Stuff is coming out of it.
16. (T) Stuff is coming out of it? How is this happening?
17. (P) I don't know.

18. (P) The paper is, the paper is ... (voice trails)
19. (T) The water is melting it and making it turn blue (restating what a child said that was not audible).
20. (T) How is it coming through the paper?
21. (P) I don't know.
22. (P) The water goes in and washes it out.
23. (T) The water goes in and washes it out.
24. (P) Dissolving.
25. (P) No.
26. (T) It's dissolving. Okay.
27. (P) The water goes up in the bag and washes the powder out.
28. (T) You think the water washes it out. It might. How does it go through that paper?
29. (P) I think it ... (voice trails)
30. (P) It bust it ...
31. (T) It burst that bag. Pick up your bag and see if it's got a hole in it.
32. (P1) No. (P2) Mine does. (P3) No.
33. (P) It is so thin it can go through it.
34. (T) It is just so thin it can go through it?
35. (P) No.
36. (P) It is.
37. (T) Denny, yours has a hole in it? Where?
38. (P) Right there.
39. (T) That's where you have got it bent.
40. (P) Oh. (Laughter)
41. (T) It doesn't have a hole in it. It must be getting out some other way.
42. (P) All that stuff is coming out.
43. (P) It smells.
44. (T) It smells.
45. (P) Yeah.
46. (P) Un - ah.
47. (T) It is melted. Did it melt?
48. (P) It's absorbing it.
49. (T) Did all yours go out?
50. (P) (Inaudible response)
51. (T) Why did the water turn blue?
52. (P) Because it was melting.
53. (T) It was melting? Why is the water blue?
54. (P) I don't know.
55. (T) The stuff made it blue. Why did the stuff make it blue?
56. (P) It was colored powder. If the powder had been purple, would the water be purple?
57. (P) Some said, "No", others, "Yes".
58. (T) Would it?
59. (P) No.
60. (T) How do you know?
61. (P) It wouldn't.
62. (T) If it had been yellow, would your water be yellow?
63. (P) No.
64. (T) How do you know?
65. (P) It just wouldn't.

66. (T) Why wouldn't it? It was blue and your water is blue. Why wouldn't your water be blue if your powder was yellow? I mean why wouldn't your water be yellow if your powder was yellow?
67. (P) But your powder was green.
68. (T) Was it green? Well, what color is your water?
69. (P) Blue.
70. (T) So what happened to it.
71. (P) It is blue green...
72. (T) Okay you can take your bag out now and just lay it there on the table. All right, let's look in that little book that you have. Look on page 16. This is where someone else has done the experiment. Look on the top; it says experimental report. All right now.
73. (P) Mrs. Smith, "Mine has a hole in it."
74. (T) Your bag has a hole in it? At the top or at the bottom?
75. (P) When I picked it up, it started dripping.
76. (T) Oh, that is why it has a hole in it, because it started dripping?
77. (P) No.
78. (T) Why?
79. (P) The bag is wet.
80. (T) Oh, the bag is wet. Why was it wet?
81. (P) Because we put them down in the water.
82. (T) Stuck it down in that liquid, huh. Alright, now let's look at this page. Right here, it says systems of interacting objects. What two things interacted on your tray?
83. (P) The color.
84. (T) The color. The color of what?
85. (P) In the water.
86. (T) The water and what?
87. (P) The powder.
88. (T) The powder. All right the water and the powder. How do you know they interacted? How do you know? Did you see them interact?
89. (P) Yes.
90. (T) How did you know that you saw them interact?
91. (P) The water turned blue.
92. (T) All right, it turned the water color. What else?
93. (P) Turned the powder color.
94. (T) Turned the powder what color?
95. (P) Green.
96. (T) All right what else did you notice?
97. (P) The green stuff ... (voice trails)
98. (T) All right, the green turned the water blue.
99. (P) Inaudible - Many responding.
100. (T) All right, Angela says the stuff in her bag was coming down in the water.
101. (P) Inaudible -
102. (T) What do you think that was?
103. (P) Green powder.
104. (T) Powder was coming down in the water. Did you ever figure out how it got down through that paper?

105. (T) I know.
106. (T) How?
107. (P) The water absorbed ...
108. (T) The water absorbed the powder --
109. (P) And made it melt.
110. (T) And made it melt.
111. (P) And it went back down in there ...
112. (T) How did it get through the paper?
113. (P) It didn't.
114. (P) It melted.
115. (P) It did right there.
116. (T) It did right there. (Laugh) How did it get through the paper? That is what I am worried about. How did the powder get through the paper?
117. (P) It melted and came out.
118. (P) It dripped.
119. (T) It dripped through. How did it drip through?
120. (P) There must have been a hole in it.
121. (P) That water bust the bag.

Mrs. Green's Lesson

Mrs. Green is teaching a second grade science class using the Laidlaw Elementary School Science Series. A segment of the tape has been transcribed for you to analyze her questioning technique.

MRS. GREEN - LIVING AND NONLIVING OBJECTS

1. (T) All right, boys and girls on page 132. Let's everybody get it, and while you're getting ready let's review the unit we had right before this one. Now this was on Matter and Energy. We had just done the planets. What's the difference, David in a planet and a star? (pause) Steve? (pause)
2. (P) A planet gets light from the sun and a star burns by itself.
3. (T) Right, that's right. Ah, is the sun a planet, Laurie, or is the sun a star?
4. (P) Star.
5. (T) The sun is a star. That's right. Okay, ah, now we had a big word Monday that meant a group of stars. A great big word, who can remember... what that ah big word was? Come on, I know some of you can get it.
6. (P) A constellation.
7. (T) A constellation is a big group of stars. Okay? (Pause) We're going to start today on our unit on Matter and Energy. Karen, would you read first for us.
8. (P) (Child reads)
9. (T) All right, now look. We talked about a long time ago that there were two kinds of things in this world. There were living things and there were things that are not alive. Kevin.
10. (P) I want to see that book.
11. (T) All right, Steve, tell me first what are some of the things...how can you tell something is alive?
12. (P) It moves and it grows.
13. (T) All right, it grows and it moves. Ah, name me something, Glenda. Name me anything in this room. (pause) Melissa?
14. (P) (Can't be heard)
15. (T) What?
16. (P) People ....
17. (T) People, all right, people.
18. (P) Animals.
19. (T) Animals, no, I don't see any animals in this room.
20. (P) Flowers and plants.
21. (T) All right, plants. Now we're naming the three groups of things that are alive. People, plants and animals. That's not what I want! I want something like the door or ceiling.
22. (T) Is the door alive?
23. (P) No.
24. (T) No, the door's not alive.
25. (P) The light isn't alive...
26. (T) No, the light isn't alive...it doesn't move, it doesn't change, it doesn't grow. It's not alive. Is that plant alive?

27. (P) Yeah.
28. (T) Is our corn alive?
29. (P) Yeah.
30. (T) Just barely, but it is alive. Okay.
31. (T) Um...
32. (T) Am I alive?
33. (P) Yeah.
34. (T) I am not moving.
35. (P) Your eyes are moving.
36. (T) Okay, I am alive. All right, our potato there is alive, isn't it? Okay, there are a lot of things here that are alive. Are there things here that are not alive?
37. (P) Yeah. Because there is light.
38. (T) Yeah, there are lights; there is ceiling.
39. (T) Robert, what are you laying on? All right, you're sitting on a chair, but your hand is on a book. Those things are not alive.
40. (T) Craig, what did you bring the other day that was alive?
41. (P) Hamster.
42. (T) All right. How could you tell he was alive?
43. (P) He was moving.
44. (T) He moved all the time, didn't he? Okay, so we know that some things are alive and some things are not alive, but all things are made up of one thing. Now, that doesn't make very much sense but we're going to find out more about it in just a minute.

Mrs. Murray's Lesson

Mrs. Murray is reviewing a textbook assignment with her 5th grade class on the topic "The Eye as an Organ."

1. (P) You use that for sight, it's like your ears,that's the organ of hearing and this is the organ of seeing or of sight.
2. (T) Okay, David?
3. (P) It does only one certain thing?
4. (T) Yes, the eye does one certain thing, that's true, but, remember when we were talking about cells, organs, tissue and systems, remember that? Well, what did we say a cell was?
5. (P) A unit of life?
6. (T) A unit of life or a building block for life. Okay, what is made up of cells?
7. (P) (Can't be heard)
8. (T) Kathy, what is made up of cells?
9. (P) Everthing.
10. (T) Yes, that's true, but, Randy?
11. (P) Protoplasm.
12. (T) Well, protoplasm; cells are made of protoplasm, but...
13. (P) Tissue?
14. (T) Tissue, that's right, and tissue makes up what other part of the body? Karen.
15. (P) Organs.
16. (T) Organs, that's right, and organs make up what?
17. (P) Systems?
18. (T) Systems. And systems make up what?
19. (P) Organisms.
20. (T) Okay, What is considered as being the organism for the eye, we'll say? The what, Charles?
21. (P) Brain.
22. (T) Not just the brain, but the what?
23. (P) Body.
24. (T) The whole human body. Now as you know too, that the eye has to have food, it has to have oxygen, it has to have ...ah oxygen, it also has to have heat...now how would you think the eye would get heat or energy? Ruth.
25. (P) From the sun when you're outside,and I guess when you look at light, it ah..
26. (T) Okay, that's one way.
27. (P) Some of it is warmth from the other parts of the body. We're warm all over and it gets its warmth from the other parts of the body.
28. (T) Okay, how does the eye get food. Joyce, tell us, how does the eye get food.
29. (P) Through your body?
30. (T) Well, through your body that's true, but how does the body get food, Joyce?
31. (P) We eat it.
32. (T) We eat it. How is food carried to all parts of the body, Joan?
33. (P) By the blood vessels.

34. (T) By the blood vessels. So you see that the eye must consist of what? One thing you know the eye must consist of is what?

35. (P) Cells?

36. (T) What? Cells. Cells and blood vessels? So these things go to make up the eye. Now do you consider the eye as being an independent organ or is it a dependent organ? David?

37. (P) Independent?

38. (T) Think, now, David, think what you're saying.

39. (P) Oh, it is dependent.

40. (T) It's dependent. Who can tell us why it's dependent? Randy?

41. (P) Because the eye has to have blood vessels and digestive system to help it see.

42. (T) Okay??? All right. It does. It does have to have blood vessels and what else helps the eye to move around and help us to see? (Pause) Okay, Wendy?

43. (P) Muscles.

44. (T) Muscles. And what else? Charles.

45. (P) The brain.

46. (T) Brains, yes...what.....think of what you're saying...the muscle...

47. (All) THE MUSCLE TISSUES, THE NERVE TISSUES AND CONNECTIVE TISSUE.

48. (T) So you see if the eye is not composed of the nerve tissue and the muscle tissues then you wouldn't be able to see because each one of them depends upon the other in order for you to be able to see. Okay, now let's turn in our books to page 231.....

ACTIVITY 2: PHRASING AND SEQUENCING QUESTIONS TO GUIDE THINKING

In this activity the participants will manipulate a physical system selected to teach a particular concept and/or generalization and write a questioning sequence that can be used to systematically guide the learning process. This will be followed by comparing their questioning sequence to a sequence offered as a model.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Introduce the activity.
2. Explain essential steps in devising a questioning sequence for instruction.
3. Organize and involve participants in writing a questioning sequence.
4. Involve participants in comparing their questioning sequence to a model.

MATERIALS LIST

For each group of 4 participants:

- 4 copies of Teaching Aid 1, Procedures for Planning a Questioning Sequence
- 4 copies of Teaching Aid 2, The Relationship Between Temperature and the Volume of a Gas
- 1 balloon
- 1 bottle, narrow neck, 1 quart, clear
- 1 large pyrex beaker (liter)

For all groups to use:

- hot water (large container at about 100°C)
- crushed ice (1 large bag)
- 1 styrofoam container

For the leader:

- 1 overhead projector
- 1 transparency of Teaching Aid 1

ADVANCE PREPARATION

Prepare a transparency from Teaching Aid 1 and make copies of Teaching Aid 2. Heat a large container of water to boiling.

Place styrofoam container of ice in an accessible location. Arrange all materials for easy access as needed.

TEACHING SEQUENCE

1. To introduce the session, say, "Proper questioning is a sophisticated teaching art. To use it well, you must anticipate the thoughts of your students and perceive their difficulties. Formulating questions that give guidance, cause conceptual conflict, and engage the students' minds make it possible for them to make their own discoveries. By doing this, you will not steal the thrill of discovery from the children, but facilitate it. By doing this, you switch from the classical concept of teaching by telling to a listening and questioning approach."

   "It is always wise to plan a series of questions before you begin a lesson. The mere fact that you have done this contributes to your questioning ability. Other questions will need to be formulated as students interact. You must remain flexible."

2. Explain that in this session participants will be involved in writing a questioning sequence to guide instruction for a hands-on science activity. In preparation for that work, a few pointers will be offered related to developing the questioning sequence.

   Distribute copies of Teaching Aid 1, Procedures For Planning a Questioning Sequence. Use the following information in explaining the handout.

   Before devising your questions, you must decide the following:

   Step 1. Where you are going. Identify the major concept(s) and/or generalizations you plan to teach. Put another way, determine the knowledge that is most important and therefore deserves the most attention. (For the science activities used in this session, the major concepts and generalizations to be developed will be specified.)

   Step 2. What are the sub-concepts which compose the major concept? For example, sub-concepts of the concept "mammal" might be "warm-blooded," "hairy body covering," "mammary glands."

   Step 3. What are the prerequisite concepts necessary for understanding the concept. In the case of the concept "mammal" prerequisite concepts might be "animal" and "living organism."

   Step 4. What are some specific facts (observations) that must be available to the child for mental processing in order to develop a conceptual understanding of the concept/generalization. In the case of mammal, the child would need to observe a variety of animals and gather observations related to differences in body coverings, body temperature, and feeding of the young. These facts could be used in sorting the animals into groups. (The word "fact" used herein means information obtained with the five senses. Facts can be reported by someone, rather than directly observed by the learner.)

Step 5. Plan out initial questions for:

a. determining if prerequisite concepts/generalizations are understood.
b. guiding students in gathering essential facts from the manipulative experience.
c. guiding thinking processes toward discovery of the concept/generalization.
d. applying the knowledge to a new situation.

Step 6. Anticipate student responses for each question. Predict likely sources of errors in thinking.

Step 7. Plan out facilitating questions as follow-up to students' initial responses.

Step 8. Organize the questions in an appropriate sequence for instruction.

3. Organize small groups of 4-5 participants. Their task is to develop a questioning sequence for an activity involving change of temperature of air in a confined space. Use Teaching Aid 2 to direct the activity. Allow at least 30 minutes for this activity.

4. Distribute copies of Teaching Aid 3, Lesson Plan: Relationship of Temperature and Volume of a Gas. Explain that this lesson plan with the questioning sequence is offered as a model to compare the sequence of questions they developed against. It is not offered as a perfect model; however, the questions have been carefully phrased and sequenced. The need to think through questions to be used in teaching hands-on science should be well established through this activity. The lesson requires understanding of the particle nature of matter which few elementary school children fully conceptualize. The lesson is more appropriate to the junior high school or high school level student.

PROCEDURES FOR PLANNING A QUESTIONING SEQUENCE

1. KNOW WHERE YOU ARE GOING. STATE THE MAJOR CONCEPT(S) AND/OR GENERALIZATION(S) YOU PLAN TO DEVELOP.
2. DETERMINE THE SUB-CONCEPTS OR GENERALIZATIONS.
3. DETERMINE THE PREREQUISITE CONCEPTS OR GENERALIZATIONS.
4. IDENTIFY THE SPECIFIC FACTS (OBSERVATIONS) THAT MUST BE AVAILABLE TO THE CHILD FOR MENTAL PROCESSING.
5. PLAN OUT INITIAL QUESTIONS FOR:
   A. DETERMINING IF PREREQUISITE CONCEPTS ARE UNDERSTOOD.
   B. GUIDING STUDENTS IN GATHERING ESSENTIAL FACTS FROM THE MANIPULATIVE EXPERIENCE.
   C. GUIDING THINKING PROCESSES TOWARD DISCOVERY OF THE CONCEPT/GENERALIZATION.
   D. APPLYING THE KNOWLEDGE TO A NEW SITUATION.
6. ANTICIPATE STUDENT RESPONSES FOR EACH QUESTION. PREDICT LIKELY SOURCES OF ERROR IN THINKING.
7. PLAN OUT FACILITATING QUESTIONS AS FOLLOW-UP TO STUDENTS' INITIAL RESPONSES.
8. ORGANIZE THE QUESTIONS IN AN APPROPRIATE SEQUENCE FOR INSTRUCTION.

Topic 4/Activity 2
Teaching Aid 1
(Transparency)

THE RELATIONSHIP BETWEEN TEMPERATURE AND THE VOLUME OF GAS

Directions:

1. Obtain the following materials from your instructor:

   1 balloon
   1 bottle
   1 large, clear pyrex beaker
   crushed ice
   hot water
   a balance

2. Stretch a balloon over the mouth of the bottle. Weigh the system and record the weight. Place the balloon/bottle system in very hot water. Observe the change.

3. Remove the balloon/bottle system from the hot water. Dry the outside of the bottle and reweigh the system. Allow the system to cool slightly in the air so the bottle won't break, and then place the system in a container of crushed ice. Distribute the ice around the bottle cooling all the surface. Observe the change. Again dry the bottle and reweigh the system.

4. Write a questioning sequence to teach the following generalizations:

   (1) The volume of a gas, such as air, changes with temperature.

   (2) Heat energy transferred into or out of a gas, such as air, causes a change in the rate of motion of the particles, and thus the spaces between the particles (molecules), causing the volume to change.

LESSON PLAN: RELATIONSHIP OF TEMPERATURE AND VOLUME OF A GAS

A questioning sequence is used (1) to solicit observations, and (2) to promote thinking about a cause-and-effect relationship involving temperature and the volume of a gas in a closed system.

BEHAVIORAL OBJECTIVES:

The children will be able to:

1. State the relationship between temperature and the volume of a gas.
2. Explain the change in volume of a gas as heat energy is transferred into and out of a closed system in terms of the rate of molecular motion and spacing between molecules.

MATERIALS:

1 balloon
1 bottle, transparent, quart size
1 large container (pyrex beaker, 2000 ml)
crushed ice
hot water, balance

TEACHING PROCEDURE:

Explain to the students that they are going to investigate changes in a system consisting of a bottle with a balloon stretched over its mouth. They will be asked to observe the system and answer questions about the changes. Stretch a balloon over the bottle making sure no air is trapped in the balloon. Ask the following questions to establish that the students have the prerequisite knowledge base to make sense of the activity:

1. What is inside this bottle?
2. How do you know that air is inside the bottle? or How could you prove that air is inside the bottle? (If no answer, ask: What would happen if you plunged an open bottle of air under water?)
3. There are three states of matter. What state of matter would air represent?
4. You have studied that all matter is composed of molecules. Name some kinds of molecules found in the air?
5. If this balloon/bottle system were placed in a container of hot water, what do you predict would happen?

Say, "Before testing your prediction, let's weigh the system on a triple beam balance." Place the bottle on the balance and adjust the riders until the system is balanced. Take the bottle away, leaving the riders in position for a comparison of weight later in the lesson. Now place the system in hot water.

6. Describe the change you observe in the balloon/bottle system. (Note change in volume and temperature.)

7. How would the number of molecules in the air inside the balloon/bottle system compare before placing the system in hot water to after placing the system in hot water?
8. How could we find out? (Hope they will suggest weighing. If not, ask question #9.)
9. If we were to weigh the system again, what do you predict? Dry the bottle carefully and place it on the balance; compare to previous weight.
10. If the weight remained the same, what caused the increase in the volume (size) of the balloon?

Children and adults will often respond that "the molecules expanded" to account for the increase in volume. They actually visualize molecules increasing in size to account for the change, rather than molecules increasing in the rate of motion and becoming more widely spaced apart. Another frequently offered answer is that the pressure increased, which it does. If they offer increase in pressure as an answer, then what caused the pressure to increase must be explored. Probing questions will be necessary to determine their present level of conceptualization and to guide their mental processes toward a better understanding. Questions such as the following could be used to probe:

a. How would you describe gaseous matter?
b. You know that gases can be compressed -- squeezed into a smaller space. What about gases makes this possible (could demonstrate by compressing air in a syringe)?
c. How large are molecules?
d. How does the distance the molecules of a gas are separated compare to the distance across (diameter) of the molecules?
e. If the gas molecules were to expand (increase in size), would they be able to fill the space between the molecules?
f. What causes a gas to have pressure?
g. If the number of collisions molecules of a gas have with each other and the walls of a container were to double, what do you predict would happen to the amount of gaseous pressure?

11. When any change occurs, a transfer of energy from an energy source to an energy receiver takes place. What was the energy source for this change? What was the energy receiver?
12. How do you think the transfer of energy might have affected the molecules of gas in the air?

If the students have problems with inferring about this, ask the following questions:

a. Have you ever walked into a house and smelled coffee brewing in the kitchen?
b. How did the molecules get from the coffee pot in the kitchen to your nose?

c. What happens as heat energy is transferred into the brewing coffee?
d. How might this be related to what is happening to the molecules of air in the balloon/bottle system?

13. Suppose we take the balloon/bottle system and place it in crushed ice; what do you predict will happen?

Have a student submerge the system in an ice-water bath. As the system loses heat energy to the surrounding ice-water, use a questioning sequence to promote obtaining and processing additional information.

14. What change in the system is now observable? (Make sure both change in temperature and volume is cited.)
15. How well did the change agree with your prediction?
16. What is the energy source for this change?
17. What is the energy receiver?
18. How do you explain this change? Follow with a probing question, if needed, such as,
    "How did the transfer of energy affect the molecules of gases in the bottle?"
19. If we repeated the heating and cooling procedure, would the same thing happen again?
20. If we used gases other than those found in the air, would the same thing happen again?
21. Temperature is a measure of the relative rate of motion of molecules. Based upon this experience, how are temperature and the volume of a gas related?
22. What picture (mental image) does this experience create in your mind about matter that is gaseous?

TOPIC 5: EVALUATION IN SCIENCE

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Much stress is placed on evaluation in schools today. Evaluation techniques provide data on student achievement which is often linked to accountability for adequate teaching. Many educators are concerned about the narrow range of science content and skills that are typically measured when tests are the principle means of evaluation. Educators also worry that time spent on testing students and record keeping limits time that can be spent on quality learning activities or adds an unrealistic burden to the teachers' out-of-class time.

These concerns are valid. The purpose of this section is to illustrate some ways to evaluate or assess many aspects of student progress in science without spending inordinate amounts of time on record keeping. Participants will receive information on evaluation and react to the information. They will work in threes to devise examples of several appropriate ways to evaluate science learning. Methods to assess progress and learning as children engage in hands-on activities will be emphasized in this section.

ACTIVITY 1: INFORMATION ON EVALUATION TECHNIQUES

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Discuss four areas of science that should be evaluated--content, process, psychomotor skills, and affective development.
2. Discuss ways to evaluate children's work in science.
3. Present questions by which teachers can evaluate their own behaviors. Invite participant comments on the topics.

MATERIALS LIST

Teaching Aids 1-18
Overhead projector

ADVANCE PREPARATION

Prepare the teaching aids. Study the teaching sequence.

TEACHING SEQUENCE

1. Present the following lecture/discussion of evaluation--its scope and purpose--using transparencies as indicated.

Scope and Purposes of Evaluation

We have discussed several "whys," "whats," and "hows" of science teaching, emphasizing hands-on experiences for children. In this session we will deal with evaluation--the "how well" of science teaching and learning. Evaluation lets us know how well children have remembered science facts and how well they can apply those facts in problem situations. Evaluation gives us an idea of how well children can construct and handle science equipment and how well they can use the science processes in activities. Evaluation can tell us how well we have fostered and maintained positive attitudes toward science.

Evaluation can and should consider at least four areas of science learning--process, content, psychomotor, and affective (Teaching Aid 1). Science process and content are largely cognitive in nature. Science processes, as we know, are the means by which we conduct scientific inquiry. They are the tools and methods of the scientist, no matter what the scientist's age is. Science content is the material to be explored. As children manipulate and construct science equipment and perform activities, their psychomotor skills are utilized and developed to the extent that they do not hurt themselves or others or the equipment. An important part of science learning involves attitudes, interests, and feelings. Most teachers hope that their students will like science and participate willingly; they want their students to develop attitudes associated with scientific inquiry and to see the study of science as valuable. Evaluation, then, should consider student behaviors in these four areas.

Evaluation can serve a variety of purposes (Teaching Aid 2). Evaluation is used to appraise achievement--to determine the extent to which children have learned science content and exhibit process skills. Formative evaluation usually takes place during instruction. The teacher observes the students as they work or discuss topics and offers feedback in terms of reinforcement, redirection, or encouragement. Formative evaluation helps the teacher guide the learners to completing a task at hand. Summative evaluation, the type most teachers probably think of when the word evaluation is mentioned, takes place after instruction has ended. Summative evaluation results are often used as the basis for assigning grades. Evaluation can also be diagnostic. It can help adults assess individual or group strengths and weaknesses. Diagnostic evaluation can help the teacher plan for appropriate future learning activities for both individuals and the group. Evaluation can also help educators to appraise students' progress in the affective domain.

2. Present the following lecture/discussion on methods of evaluating children's science learning--using transparencies as indicated.

Methods of Evaluating Children's Science Learning

In science, as in other curricular areas, many means of evaluating children's learning are available. Different techniques are suited to evaluation of different behaviors. Use of a variety of evaluation techniques gives a better picture of student progress or achievement than does use of a single technique.

We will talk about a number of techniques for evaluating children in science (Teaching Aid 3). These include evaluation of:

Laboratory or Hands-on Work
Student Reports
Recitation and Discussion
Project Work
Written Tests
Attitudes, Interest, and Feelings

In hands-on work, with materials and equipment, we judge the children's use of the science process and their psychomotor skills (Teaching Aid 4). To evaluate process behaviors, teachers must be aware of the meanings of the processes and note the children's skill in using them. For example, as children test and observe objects that float and sink (Teaching Aid 5), the teacher should note whether the children predict what objects will float and sink, actually try out the objects, manipulate the objects in different shapes and positions, keep track of their results, or try to explain the results. If children work in a group, the teacher might note the roles that different children take--who is a passive observer, who is a leader, who takes "orders" well, who does not detract from the activity with inappropriate behaviors, who suggests reasons for the results, who makes effective predictions (Teaching Aid 6)?

Here is another example of what the teacher might look for as children are actively involved in science inquiry (Teaching Aid 7). Suppose that third graders are working in groups of four. Each group is given a box that contains two mealworms in some cornmeal and a hand lens. The children have access to rulers, pencils, and papers. The children are asked to find out as much as they can about the mealworms. The teacher might note things such as these: Who suggests observations to make? Are any measurements made? What qualitative observations are made? Do the children act on the mealworms, trying to get them to move, turn over, or react to stimuli? Do the children record or draw sketches of observations? Do they make any predictions or inferences? What additional things might the teacher observe?

Let's look at one more example (Teaching Aid 8). Suppose that after several experiences in being guided through the steps in conducting an experiment, sixth graders are asked to work in groups of four, devise an experiment on plant growth, and carry out the experiment over a period of two weeks. The groups are given ample time to discuss, plan, and set up their experiments, then are allotted shorter periods of time to check on their results once the experiment is set up. Throughout the two week period, the teacher might note the following: Do the groups generate testable questions and hypotheses for their experiments? Do they consider and control pertinent variables? Do they manipulate the variable that will help them answer their question? Do they observe and record observations in a consistent and effective manner? Do they make inferences based on their data? Did group members share the work? Were groups responsible in caring for their plants? What else would you add to this list?

If clear instructions are given and children are used to laboratory work, the teacher becomes relatively free to circulate and see what students are doing. The teacher can then use a checklist to record student behaviors. Perhaps second graders will do several experiences in classifying over a two-week period. The teacher might use a checklist such as this (Teaching Aid 9) to evaluate the children's behaviors.

The teacher can also use individualized questioning to assess the children's understanding of content and processes. If the children are categorizing rocks, the teacher might ask individuals to explain why certain rocks were classified as they were or to explain what the classification names meant. General questions such as "What are you doing here?" and "What are you learning?" give the teacher information on the children's understanding of laboratory work. As groups share experimental results, teachers can probe their understanding with individualized questions. Teachers or children can also ask the class what questions they have about experimental results.

Children can also be asked to demonstrate parts of their hands-on work. These demonstrations may be done as the children work in groups or may be performed in front of the entire class. In the mealworm example, perhaps one group "tested" their mealworms to see if they would back away from objects placed in front of them. The group carefully moved an object toward the mealworm, then observed the results. Because no other group thought of this, the teacher might ask a child to demonstrate and let everyone see the results. For another example, a teacher might ask each child in a group to demonstrate the safe lighting and disposal of matches before the group is allowed to work with matches in a laboratory exercise.

Where individuals or groups are to record results or write records of laboratory work, the teacher might collect and evaluate these (Teaching Aid 10). The teacher might look for things such as reasonable results and measures, following directions, careful sketches of results, correct statements of results, and neatness and clarity. Most teachers find that children produce better written results with much formative guidance. That is, when teachers spot-check work and guide children as to where it could be improved or what data might be rechecked, the final products will be better.

We have already touched on student reports of laboratory work. It is also often appropriate for students to make oral or written reports of their research. Student reports involve content as well as language skills. Reports may be as simple as a kindergartener telling what she has "read" in the words and pictures of a book about ants or as complex as a written and illustrated booklet by a sixth grader on Saturn's rings. Results of reports must be evaluated in terms of the child's grade and developmental level. Because of their age, experience, and schooling, third graders can be expected to produce more sophisticated results than kindergarteners. In evaluating reports (Teaching Aid 11), teachers might look for factors such as clarity and accuracy of information, creativity shown by the child in organizing or completing the report, skill in language usage, and amplification of the topic by use of visual aids. If the report is oral, the teacher will note the child's poise and enthusiasm in speaking to classmates. If the report is written, the teacher may wish to consider neatness and correct grammar and spelling in the evaluation.

Teachers might want to use a checklist or short evaluation form when assessing reports. Results may be discussed with children individually. The teacher makes narrative comments on a written form; the form may be given back to the children. Evaluation should help children improve their work. For younger children, just participation in making reports may be all that is expected. For older children, identification of specific strengths and weaknesses will be more helpful than simply receiving a mark of "B" or "poor."

Students often engage in activity work that results in a product or project. For example, a group of fifth graders may work together to make a "run off tray" to illustrate the effects of erosion on terraced and nonterraced soil. Younger children might plant grass to simulate a grassland habitat. The children could add clay and paper models of animals and other details to complete the grassland environment. Such projects let children use and refine their psychomotor skills and to convey their knowledge of science content. Children often also use the science processes as they engage in project work. To be effective, projects must be meaningful. They must have a purpose other than "busy work" or extra credit. Some projects should be done in class.

Evaluation of projects is similar to evaluation of laboratory work (Teaching Aid 12). Teachers must know what to look for and collect data by observing project results. If children work in groups on projects, teachers may also wish to consider aspects of the ways children work together in their evaluations. If children explain their projects to others, teachers can also note the ease, clarity, and thoroughness of their explanations.

Written tests (Teaching Aid 13) are commonly used to evaluate children's understanding of science content. Tests may include true-false, multiple choice, matching, or fill-in-the-blank items. Most often these types of items test factual knowledge, but do not go beyond that basic level in their scope. Teachers should consider short answer questions in which children explain phenomenon or solve problems based on application of facts they have learned. Essay questions--which must be short ones for most elementary children--sample a relatively small number of concepts, but show whether children can organize their thoughts, give adequate explanations, and apply known facts. In short essay questions, children might explain what happened in previous science experiences. They might tell how to design a simple experiment to answer a question. Teachers might also include questions that require children to sketch and label diagrams for their answers.

Written test items can also give indications of children's understanding of science processes. Children might be asked to record observations, explain how they would design an experiment, or make inferences based on observation of actual materials. Test items of this sort complement and supplement teachers' observations of children at work in laboratory situations. Written tests might include just one or two or several hands-on questions.

When educators are attempting to measure children's science knowledge and skills with written tasks, they must remember that success on written tasks depends to a large extent on the children's language abilities. Objective test items are often as much measures of children's reading levels as of their science knowledge. Short answer and essay questions require skill in writing which may or may not relate to children's understandings. That is, some children are quite capable in science, but because of poor language skills, don't perform well on written tests.

Appraisal of affective objectives is often done less directly than the appraisal of cognitive and psychomotor objectives. Since we can't get inside children's heads and actually see what they're thinking, educators must make judgments of children's attitudes and feelings based on the children's behaviors. A goal or objective of a school's science program may be that the children will develop or sustain interest in science. To evaluate the objective (Teaching Aid 14), educators use an operational definition of interest, perhaps observing children to see whether or not they volunteer to answer questions, do activity work, or look for additional information on science topics. When given a choice, children who choose science activities or books consistently might indicate interest in science.

Teachers may also judge interest by thinking about questions the children ask and pursue or express interest and enthusiasm. What other behaviors might children exhibit to indicate interest in science?

Teachers can keep records of patterns of children's interest. A teacher could mark a checklist like this one every couple of weeks (Teaching Aid 17). By noting the frequency of behaviors such as the ones we discussed, the teacher gets an overall picture of the children's interest level. Use of checklists helps educators to focus on pertinent student behaviors and helps to eliminate subjectivity in making judgments.

Educators might also be interested in children's development of scientific attitudes (Teaching Aid 15). They might be interested in factors such as curiosity, open-mindedness, persistence, respect for the ideas of others, or allowing one's ideas to be questioned. What other factors might be considered as indicating scientific attitudes?

Other affective factors such as cooperation and assumption of responsibilities are also important in elementary school science. Again teachers might record their observations of children's behaviors on a checklist (Teaching Aid 16). They could include items such as assuming responsibility for equipment, taking responsibility and showing respect for living specimens, taking part in cleanup activities, exhibiting appropriate classroom behaviors, and following instructions. What other factors do you look at when trying to judge a child's cooperation or responsibility? Use (Teaching Aid 17) for written suggestions on affective development. Have participants add suggestions to it.

Grading and reporting to parents are realities in today's schools. To make balanced assessments of children's abilities in science, it is important to gather a wide variety of kinds of evaluative data. Many aspects might be considered when assigning grades. Teachers might include:

Daily grades on activities, group work, and lab sheets.
Checklist data on student's ability to work with others.
Activity work that results in a project or product.
Test Grades.

Some schools also include separate categories for effort and attitudes on report cards and reporting devices.

3. Present the following lecture/discussion on methods of evaluating the teacher's role.

Methods of Evaluating the Teacher's Role

We hear almost as much about evaluation of teacher effectiveness today as we do about evaluation of student achievement. Often teachers are evaluated by others--peers, supervisors, administrators, or outside evaluators. To promote positive feelings about evaluation and fairness, teachers should know in advance the factors on which they are to be evaluated. Will they be judged by their students' standardized test scores? Will they be evaluated by use of the Mississippi Teacher Assessment Instrument? If so, what are the indicators of effectiveness on each of the sixteen competencies? Are they to be judged on what they understand to be their principal's perception of "good" teaching? On what other bases are teachers evaluated?

Teachers can also assume responsibility for evaluating their own classroom behaviors. Some teachers analyze audio- or video-tapes of their teaching. To get more than a global view of fleeting impressions of how they sounded or looked, teachers must use some sort of criteria as they listen to, or look at, themselves. They might be interested in such factors as giving clear directions for group work, ability to sustain discussion, or meaningful demonstrations. If so, they must focus on these factors as they replay the records of their classroom behaviors.

Teachers can also try to reflectively answer a series of qualitative questions pertinent to the teaching of science. The questions could be generated based on the goals and objectives of their programs. Your teaching aid gives suggestions for questions. (Teaching Aid 18. Allow several minutes for participants to look over the sheet.) What other questions would you add to the list? Teachers could use questions of this sort individually or with a group of peers. The questions will focus attention on different aspects of teaching. As written, they are mostly nonjudgmental. Teachers will have to judge whether the methods or perceptions the questions help them address are good or bad, effective or not-so-effective.

(Give participants several minutes to think about the questions and let them discuss some answers to the questions and problems they encounter as they deal with the factors suggested by the questions.)

AREAS FOR :

SCIENCE EVALUATION

Cognitive development

- process
- content

Affective development

Psychomotor development

Topic 5/ Activity 1
Teaching Aid 1
(Transparency)

PURPOSES OF EVALUATION

- Appraising achievement

  formative

  summative

- Diagnosing strengths and weaknesses

- Appraising affective development

Topic 5/ Activity 1
Teaching Aid 2
(Transparency)

SOME AREAS OF EVALUATION FOR SCIENCE

- Lab or hands-on work
- Student reports
- Recitation and discussion
- Project work
- Written tests
- Attitudes, feelings, interest

Topic 5/ Activity 1
Teaching Aid 3
(Transparency)

Evaluating

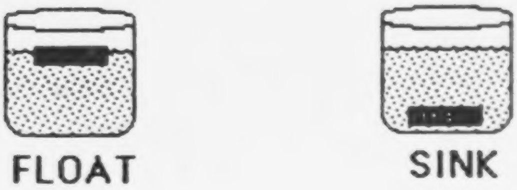
HANDS-ON WORK

Look for

- skill in using processes
- psychomotor skills

Topic 5 / Activity 1
Teaching Aid 4
(Transparency)

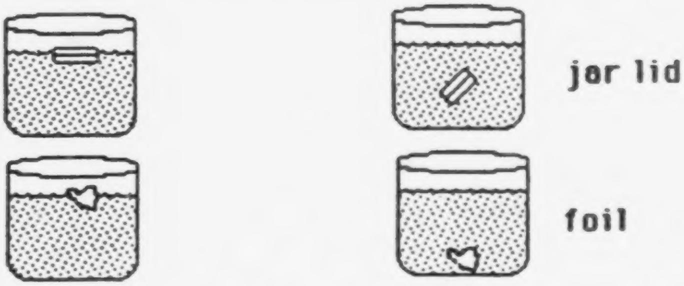
Specific Observations



Do children predict?

Do they try out objects?

Do they manipulate objects?


jar lid
foil

Do they record or sort data?

Do they try to explain?

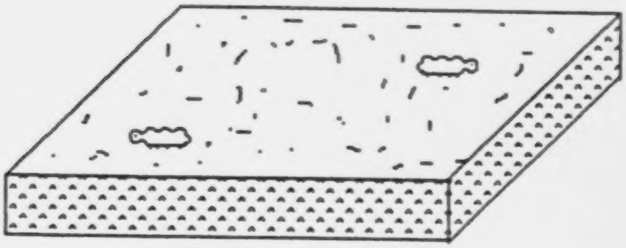
Topic 5 / Activity 1
Teaching Aid 5
(Transparency)

GROUP BEHAVIORS

Who is active? passive?
Who leads? follows?
Who takes directions well?
Who behaves cooperatively?
Who suggests inferences?
Who predicts?

Topic 5 / Activity 1
Teaching Aid 6
(Transparency)

SPECIFIC OBSERVATIONS



Who suggests observations?

What kinds of observations?
  qualitative
  quantitative

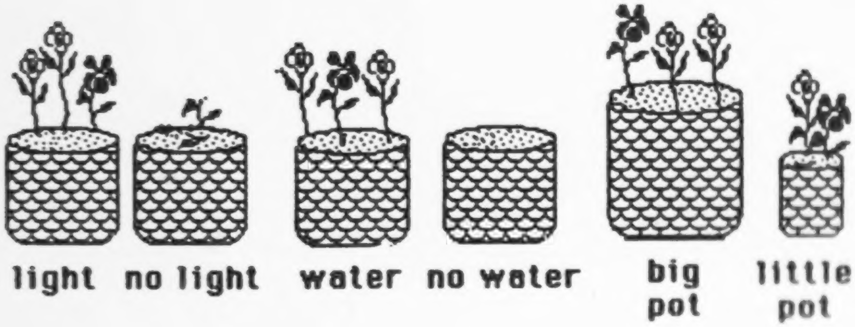
How did children act on the mealworms?

Data recorded?

Predictions or inferences made?

Topic 5 / Activity 1
Teaching Aid 7
(Transparency)

SPECIFIC OBSERVATIONS . . . DESIGNING AN EXPERIMENT


light
no light
water
no water
big pot
little pot

Testable questions and hypotheses?

Pertinent variables?
- considered?
- manipulated?
- controlled?

Records of observations?

Inferences based upon data?
Work shared?
Responsible attitudes?

Topic 5 / Activity 1
Teaching Aid 8
(Transparency)

✓CHECKLIST FOR CLASSIFYING

Behavior	**Children**										
Sorts objects according to given criteria											
Devises criteria for classifying											
Classifies according to several criteria											
Names basis for Classification											
Discusses thinking about work											
Makes subclassifications											

Topic 5 / Activity 1
Teaching Aid 9
(Transparency)

EVALUATING LAB REPORTS OR RECORDS OF RESULTS

Reasonable measures and results

Careful diagrams and sketches

Correct statements of results

Following directions

Clarity of words or pictures

Neatness

Topic 5 / Activity 1
Teaching Aid 10
(Transparency)

EVALUATING
WRITTEN AND
ORAL REPORTS

Clarity

Accuracy of information

Creativity

Skill in language usage

Effective use of visual aids

Poise, enthusiasm of oral work

Neatness, grammar, spelling of written work

Topic 5 / Activity 1
Teaching Aid 11
(Transparency)

EVALUATING PROJECTS

Does the project:
  Illustrate or convey information?
  Represent creative work?

Was the project:
  Neatly made?
  Ably explained?

For group projects:
  Did children share the work?
  Did they work together cooperatively?

Topic 5 / Activity 1
Teaching Aid 12
(Transparency)

WRITTEN TESTS

Objective Items

True - False	Matching
Multiple choice	Fill-in-the- blank

Essay or Short Answer Items

- Examples
- Explanations
- Applications
- Require organization

Sketching Answers, Making & Labeling Diagrams

Topic 5 / Activity 1
Teaching Aid 13
(Transparency)

EVALUATING INTEREST IN SCIENCE

Some indicators of interest...

- Volunteers for questions
- Volunteers for activities
- Does additional research
- Chooses science (when has a choice)
- Asks pertinent questions
- Expresses interest, enthusiasm

Topic 5 / Activity 1
Teaching Aid 14
(Transparency)

EVALUATING DEVELOPMENT OF SCIENTIFIC ATTITUDES

- Curiosity
- Open- mindedness
- Persistence
- Respect for ideas of others
- Allowing one's ideas to be questioned

Topic 5 / Activity 1
Teaching Aid 15
(Transparency)

EVALUATING
COOPERATION
RESPONSIBILITY

- Cares for equipment
- Respects living specimens
- Cleans up
- Behaves appropriately
- Follows instructions

Topic 5 / Activity 1
Teaching Aid 16
(Transparency)

CHECKLIST FOR SOME ASPECTS OF CHILDREN'S AFFECTIVE DEVELOPMENT IN SCIENCE

	Students' Names							
Volunteers to answer questions								
frequently								
sometimes								
seldom								
Volunteers to take part in science activities								
frequently								
sometimes								
seldom								
Does additional research on science topics								
frequently								
sometimes								
seldom								
Chooses science over other activities								
frequently								
sometimes								
never								
Asks pertinent questions about science topics								
frequently								
sometimes								
never								
Expresses interest or enthusiasm about science topics and activities								
frequently								
sometimes								
never								

EVALUATING THE TEACHER'S ROLE IN THE SCIENCE PROGRAM

What is the focus of my science program--acquisition of facts, development of concepts, development of process skills, or a combination?
  What affective goals are included?
  What do I do to emphasize the focus?
  From day to day, how do I work toward the focus?

How do students react to class activities?
  What proportion of students are typically actively involved?
  What proportion of students are typically seemingly bored?
  What proportion of students volunteer in discussions?
    In hands-on work?

How do I handle lab work or hands-on experiences?
  How often do I actually involve students in hands-on experiences?
  Do I plan a prelab (motivation, directions), lab (actually doing the work), and postlab (sharing results) phases?
    How do these phases generally work? Are students interested? Do they work constructively and without disruptions? If noise and activity levels are excessive, how can I bring them to an acceptable level?
  What group sizes do I use for hands-on work?
  What factors limit the lab work I can have students do? How do/could I work to overcome these factors?

How do I try to meet individual needs of students?

How do I accommodate student interests?

What choices of assignments or ways of working on assignments do I offer students?

Do I provide a variety of resource materials?
  Do I use books and magazines on different reading levels?
  Do I use realia?
  Do students share reading materials or realia?
  What additional resources could I add?

In what ways do I try to motivate students?

How do I show students the pertinence or value of the topics we are studying?

How do I introduce topics? How could I add more interest to introductions?

What are some different ways I have students study science content?
  What sort of balance do I provide between hands-on and book work?

- What field trips or outside experiences would complement the science topics I teach?
- What resource persons could help me?

How do I summarize or conclude study of topics? How could I have students assume more responsibility for summary or review activities?

Do I use a variety of teaching techniques?

Do I use a variety of appropriate techniques?

ACTIVITY 2: EVALUATION TECHNIQUES FOR SPECIFIC ACTIVITIES

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Using a prepared handout, illustrate ways of evaluating content, process, psychomotor and affective learning outcomes for a hands-on science activity.

2. Engage participants in studying and discussing evaluation techniques described for two additional hands-on science activities.

3. Involve participants in developing an evaluation plan for an activity that has been described on the prepared handout.

4. Guide participants in sharing and discussing the evaluation plans they developed.

5. Involve participants in developing an evaluation plan for a hands-on science activity that they select and describe.

6. Guide participants in assessing their evaluation plans for the activities.

7. Assign the development of an evaluation plan for a textbook topic.

MATERIALS LIST

For each participant a copy of Teaching Aid 1, Evaluation Techniques For Hands-On Science.

ADVANCE PREPARATION

Duplicate the handout, Teaching Aid 1, and study the teaching sequence.

TEACHING SEQUENCE

1. Distribute copies of Evaluation Techniques For Hands-On Science, Teaching Aid 1, to participants. Explain that the handout gives specific examples of involvement activities for children and suggests ways to evaluate them. For example, Activity 1 is an experimental situation in which young children investigate the effects of light and dark on four kinds of plants. Evaluation techniques would let the teacher appraise the children's knowledge of content; their skills in using the processes of observing, recording data, and making inferences; their psychomotor skills used in planting and caring for the plants; and

some specific affective behaviors. Evaluation techniques include assessment of discussion and written work, and the use of checklists of teacher observations.

2. Direct participants to study activities 2 and 3 and the suggested evaluation techniques. Allow a few minutes for study and then use the following questions to promote discussion:

   - What methods of evaluation do you find especially appropriate?

   - What additional methods would you suggest?

   - What other areas would you evaluate?

   - What questions or comments do you have?

3. Organize the participants in groups of three. Assign each group either activity 4 or 5. Instruct the groups to study the assigned activity and to develop an evaluation plan. In the plan, they should propose the areas to be evaluated and suggest specific techniques for each area. Allow time for participants to work.

4. Ask each group to share their evaluation plan with the entire group. Encourage discussion of each plan.

5. Return to the previously organized small groups for further work. Assign the groups the task of identifying a hands-on experience and writing a description of the activity in the space numbered 6 on their Teaching Aid. After describing the activity, they are to write evaluative techniques for the activity.

6. Let each group briefly describe their activity and evaluation plan. Use the following criteria in assessing their plans:

   - The evaluation techniques are appropriate for the kinds of programs, goals, and activities they purport to assess.

   - Techniques are not limited to solely paper and pencil tasks.

   - A wide variety of techniques are used.

7. If time permits have participants take a textbook topic and develop an evaluation plan for the topic.
(This may be given as an outside assignment.)

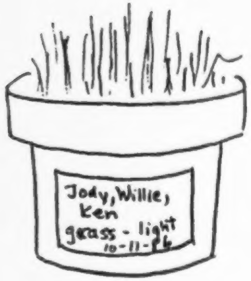
Topic 5/Activity 2

Teaching Aid 1

EVALUATION TECHNIQUES FOR HANDS-ON SCIENCE

Activity

I. Young children investigate whether plants grow better in light or dark. In separate pots, they plant grass seed, alfalfa, radishes, and lima beans. They place four pots in the closet and four on the window sill. They observe the pots daily, water then as needed, and record results.



Evaluation

Content. Use oral discussion to evaluate the children's understanding of the following:

What factors might affect plant growth?

What is happening to your plants?

Have each child write a summary paragraph on what happened in the activity. Children who can't write effectively could draw pictures and perhaps label them.

Process. Use a checklist to record the following:

Do children follow directions?

Do they observe various aspects of plant growth--color of plants, size and positions of stems, amount of water that is needed?

Do they keep careful records?

Do they label their specimens?

Do they make reasonable inferences?

Psychomotor. Use a checklist to record the following:

Do children handle dirt and seeds without excess mess?

Do they pour water skillfully?

Affective. Use a checklist to note the following:

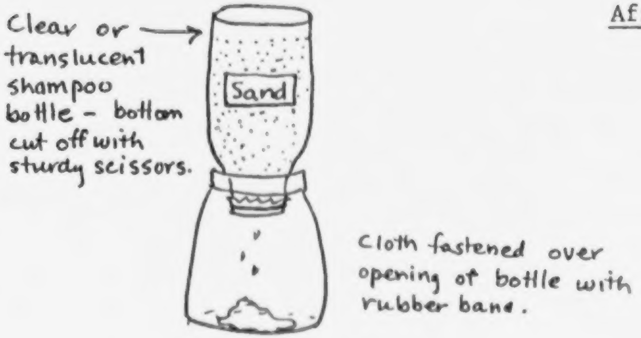
Do children seem enthusiastic about the activity?

Do they share the work?

Do children assume responsibility for caring for their plants?

Do they seem pleased with the growth of their plants?

II. Children work in groups with 2 soil samples and with sand. They are to do a controlled experiment to determine which holds more water and which holds water the longest. They set up soil samples in plastic bottles as shown. They are to make predictions, then pour 100 ml water through each sample and record how much water drips through.


Clear or translucent shampoo bottle - bottom cut off with sturdy scissors.
Sand
Cloth fastened over opening of bottle with rubber band.

The children make a written report of their data and conclusions about the samples. Finally, they clean up their materials.

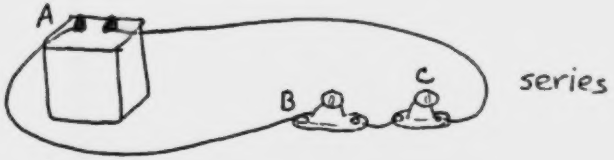
Content. Check the children's written reports. Include a test question on the next test concerning the ability of sand to hold water compared to loam.

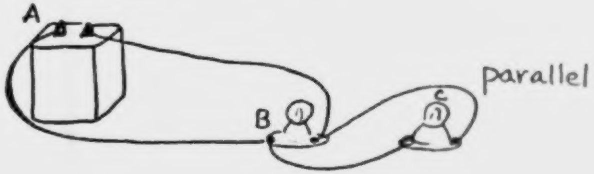
Process. Check the children's written reports to determine the following:
- Did they control amounts of soil, sand and water?
- Did they keep reasonable records of times and water that dripped through?
- Did they make reasonable inferences?

Psychomotor. Use a checklist to record the following:
- Did children handle the materials skillfully enough to avoid making a mess?
- Did they clean their materials?

Affective. Record the following on a checklist:
- Did the children all take part actively?
- Do they share the work?
- Do children assume responsibility for caring for their plants?
- Do they seem pleased with the growth of their plants?

III. Children read about parallel and series circuits and their advantages and disadvantages. They work in groups to set up parallel and series circuits following diagrams from the textbook. They predict what will happen if they disconnect the bulbs or wires at points A, B, and C, then test out their predictions





Content. Use oral discussion to evaluate the children's understanding of:

Similarities and differences in the two types of circuits.

Reasons the circuits were broken or unbroken at points A, B, and C.

Advantages and disadvantages of each type of circuit.

Include test questions on the next test:

Draw and name each type of circuit.

Study diagrams of several setups.

Tell if the bulbs will light or not and why.

Process. Use a checklist to record:

Do the children follow directions?

Do they make reasonable predictions and inferences?

Psychomotor. Use a checklist to record:

Can the children handle the equipment skillfully?

Affective. Use a checklist to record:

Did the children appear to be curious and enthusiastic about the activity?

Were the children careful in handling the equipment?

Did they share the work?

Add appropriate evaluation techniques for the following activities. Use areas of content, process, psychomotor, and affective as appropriate.

IV. Children work in groups to prepare reports on each of the planets. They are to gather and convey facts to their classmates as well as make a model or picture of their planet or its surface.

V. Children classify materials as to whether they attract or don't attract to a magnet.

Now add another activity and appropriate evaluation techniques.

VI.

TOPIC 6: EFFECTIVE USE OF TEXTBOOK MATERIAL

Kay Camperell
University of Southern Mississippi

The recent report of the Commission on Reading (Anderson, Hiebert, Scott & Wilkinson, 1985) recommends that reading and thinking skills instruction in the intermediate grades should focus on helping students acquire strategies for coping with subject-matter texts. This recommendation is based on an extensive review of current research and theory in reading. Results of this research reveal that reading and thinking skills are knowledge-based processes in which students use what they already know to make sense out of familiar information and to reason about new ideas. Most commercial reading programs are designed to help children in the primary grades learn how to read about ideas and events that are familiar to them. While these materials can help students learn how to read, they cannot be used to teach students how to use reading as a tool for learning from subject-matter texts.

Most textbooks confront students with information that is new to them, divorced from personal experience, and fundamentally different from the information and structure of materials in basal readers. Subject-matter texts are designed to convey the facts, concepts, generalizations and structures of various disciplines, and students should not be expected to read content materials without instruction and guidance. Much of this instruction, particularly in science, should consist of helping students acquire the background knowledge needed to comprehend science texts. Such instruction is crucial if students are to become proficient readers because learning how to read content textbooks requires that students develop new knowledge and new skills. This also means that teachers must know how to help students acquire new knowledge and develop skills appropriate to learning from textbooks.

The thinking and reading skills needed to understand science texts are essentially the same as those students must engage in as they learn about the facts, concepts and generalizations that make the field of science a distinct discipline. Many of these strategies are the same as the integrated science processes presented in previous workshops (see Topic 3). Reading to learn from science books involves applying more complex types of knowledge and information processing strategies than those students learn in the primary grades. The key to effective reading instruction at the intermediate level, therefore, is to guide students in using what they learn through science activities and experiments to elaborate and grasp the significance of information they read. This means that the kinds of instructional activities discussed in other sessions should precede the reading of science passages so that (1) students have a mental framework for understanding what they read, and (2) students can learn to apply new knowledge and processing strategies when they read science materials.

Such an approach to reading instruction is not new; yet, results of observational studies suggest that many teachers in the intermediate grades do not employ the approach when they have students read content materials. One reason for this may be that teachers do not understand how the knowledge students bring to the texts and the strategies they employ influence what they understand and learn from reading. Nor do teachers understand how content textbooks differ in many ways from basal reading materials. Thus, the initial activities of this session are designed to help teachers acquire a conceptual understanding of the nature of reading processes and the features of textbooks that influence those processes. Subsequent activities will engage teachers in analyzing and evaluating a chapter from a science text and then developing an instructional plan for guiding students through the chapter.

Many of the ideas presented in this workshop relate to recent guidelines for evaluating and selecting textbooks. A bibliography is provided for those interested in that area; however, emphasis in this workshop is on learning how to evaluate texts for instructional purposes.

ACTIVITY 1: THE NATURE OF READING PROCESSES

This activity is designed to introduce participants to several key concepts and generalizations about reading. The goal of the activity is for participants to become aware of how students' prior knowledge and experience influence reading comprehension.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The primary role of the workshop leader in this activity is to guide participants in reading several passages and making generalizations about factors that influence reading performance. The workshop leader's behavior in summary form follows:

1. Present four passages for participants to read and discuss. For each passage:
    a. Guide discussion of answers to questions about the passage as well as participants' reactions to the passage.
    b. State or lead participants to state a generalization or name a concept related to the types of knowledge students need to become proficient readers. The term concept is used to refer to key terminology related to reading (e.g., vocabulary, syntax, etc.). The term generalization is used to refer to statements that summarize or explain groups of related ideas and to statements that predict reading performance.
    c. Summarize key generalizations derived from reading and discussing the passage.
2. Summarize major understandings and generalizations made about factors that influence reading performance after all the passages have been read and discussed.
3. Present an overview of how the ideas discussed in this activity will be expanded upon and used in subsequent activities.

MATERIALS LIST

For each participant a copy of each of the four passages.
Chalk and/or supplies for using a transparency to list generalizations discussed.

ADVANCE PREPARATION

Duplicate sufficient copies of the passages so that participants have their own copies. Since many of these ideas may be new to workshop leaders, they may want to read some of the articles listed in the bibliography at the end of this activity. It is recommended that the leader read the article by Eaton, Anderson, & Smith (1984), "Students' Misconceptions Interfere with Science Learning."

The key to preparing for this activity is for workshop leaders to understand themselves the concepts and generalizations to be introduced.

Key concepts and generalizations to be developed are:

1. Reading involves using knowledge of language, ordinary events in society, and the topic addressed in the text (Passages 1 & 2).

2. Correct pronunciation and answers to questions may mask comprehension failures (Passages 2 & 3).

3. Students may have the appropriate background knowledge but fail to use it (Passages 2 & 3).

4. For every text and reader, there are various levels of understanding. These levels vary according to the background knowledge and experience of the readers (Passages 2, 3, and 4).

5. Understanding involves knowing how ideas are related and grasping the significance of the ideas (Passages 2, 3, and 4).

6. The meaning of any text depends upon the knowledge a reader employs to understand it (Passage 4).

7. Prior knowledge can impede, as well as facilitate, comprehension (Passage 4).

TEACHING SEQUENCE

1. Explain to participants that members of the group need to establish a common conception of what reading is and what factors influence reading performance. To do this, you are going to ask them to read and respond to several passages.

   Distribute the first passage "A Marsden Giberter for Farfie." Tell the participants that this is a story about a common event in most Americans' lives. Even though the text may look like gibberish, they are to keep trying to read it until they can come up with the "real" title for the passage.

   A. If after 3-4 minutes have passed and participants still look confused, stop. Ask them to tell you what they can say for sure about Glis (she is a female) and Farlie (he is a male).

Then, direct them to continue reading until they can give you the title of the passages. If most participants still look confused, remind them that the story is about a common event in our society, something each of them has experienced.

B. When most participants have written a title for the passage, ask for volunteers to state their titles and explain how they figured out the title. Usually someone comes up with the title "A Birthday Present for Farfie."

(1) List on the board the features of the text that provided clues about the meaning of the story. The list should include: knowledge about the conventions of writing (punctuation), knowledge about pronoun usage, and knowledge about word order (syntax).

(2) Ask participants if they could have figured out the meaning of the passage from the written words alone, the punctuation, or word order. Lead them to state that their knowledge of birthdays enabled them to make sense out of the "words" on the page. Explain that this kind of knowledge about an ordinary event in our society allowed them to use the punctuation, pronoun, and syntax clues. Thus, reading involves more than being able to pronounce words. It also involves using various types of knowledge to make printed words make sense.

C. Summarize for participants the types of knowledge they used to read the passage (knowledge of language, knowledge of ordinary events in society, and knowledge of conventions of writing). Stress that using what they already knew allowed them to eventually understand the passage. And, understanding is what reading is all about.

2. Distribute Passage 2, "Washing Clothes." Direct participants' attention to the ordinary sentences and words in this passage. Again, explain that this passage describes an ordinary event in most of our lives. Ask them to read the passage silently and answer the questions that follow it.

A. When most participants have finished answering the questions, have volunteers give answers to questions a-e. Each of the questions can be answered with direct quotes from the passage. These are typical of the answers most people provide.

B. After the questions have been answered, ask for the title of the passage. Usually, participants volunteer titles such as "The Procedure," "Cycles of Life," "Office Work," or "Washing Clothes."

Write each title on the board (an overhead), then guide participants' attention to how the significance of the facts, events, and words change with each title. To do this, go back and ask questions a-e again. Or, ask questions about how the meanings of various words change with the different titles (e.g., groups, facilities, mistakes, places).

(1) Discuss with participants the point that many people can correctly pronounce all the words in a passage and answer questions about it, yet fail to understand what they have read. This happens quite often to students in schools. Have participants give examples of situations where they have had such an experience.

(2) Discuss with participants the point that many people have the prior knowledge to make events in a passage make sense. However, until they use that knowledge, statements and events in passages seem vague and disconnected. They have "read" the passage with only a slight or fuzzy degree of understanding. Again, have participants discuss how this happens to students in school.

If participants cannot think of personal examples from their own experience, ask them to talk about reasons why they preteach vocabulary and have discussions prior to reading stories in basal reading lessons. Participants should be able to explain that these activities are designed (a) to relate events in stories to students' prior knowledge and experience, and (b) to help students acquire new knowledge (vocabulary) related to the story. Point out that these same kinds of activities should precede any reading assignment.

3. Distribute Passage 3, "Christopher Columbus." Ask the participants to read the passage silently and to invent a title for the passage.

   A. When most have written down a title, have volunteers state the titles they invented. Most will say "Christopher Columbus," or "Columbus Discovers America." Some, however, will give more general or vague titles like "Exploration" or "The Discovery." Probe these responses.

   B. Ask participants where they acquired knowledge about Columbus. Point out that knowledge about the discovery of America differs from knowledge gained through personal experience and knowledge about ordinary events like birthdays.

Emphasis should be placed on the fact that they learned about Columbus in school or from someone else, but none of them personally experienced the discovery of America. Point out that most of the information in school books is like that. Students are expected to acquire such information as they progress through schools and then use it to understand new information in subsequent chapters, grades, or classes.

Direct participants back to the passage and have them explain how their knowledge about the discovery of America allowed them to tie the ideas in the passage together and to elaborate the meaning of the words. Ask questions that highlight how prior knowledge, not the words on the page, tied the words within and between sentences into an event that was understandable. Examples of such questions are:

(1) Whose gems were hocked?

(2) Why was there scornful laughter? What was his scheme?

(3) Who were the three sturdy sisters?

(4) What fearful edge did doubters spread rumors about?

(5) What were the welcome winged creatures? What did they signify?

C. Summarize with participants the key generalizations discussed:

(1) Understanding involves knowing how ideas are related and grasping the significance of the ideas.

(2) Readers must have knowledge related to the topic of a text or they will not be able to see how information and events they read are related.

Point out to participants that much of the knowledge children need to become proficient readers is acquired through schooling--through learning about ideas and events that are new and different from those acquired through out-of-school experiences.

4. Distribute Passage 4. Ask participants to read the passage silently and answer the question that follows it.

A. When most participants have selected an answer, have volunteers tell which response they chose and why they chose it. Some will select choice "b," others choice "d."

Discuss with participants how each choice was correct depending upon the knowledge or perspective they used to relate the events in the passage. Have them explain how the significance of key words and phrases varied depending upon which topic they used to interpret the passage. Examples of words to focus on are:

(1) Writing some notes

(2) Gathered the cards

(3) Couldn't agree on what to play

(4) Jerry took a stand

(5) Karen's recorder

(6) Pat's hand and many diamonds

(7) Jerry pondered the arrangement in front of him

(8) Let's hear the score

(9) Tempo of play increased

(10) They commented on their performance

B. Ask participants how or why some of them automatically interpreted the passage as a card game or a musical performance. Ask if either interpretation is right or wrong, pointing out how the significance of the words changed with each interpretation. Then discuss with them how the meaning of the text varied depending upon the knowledge used by individual readers to create a meaning. Since there was no title to establish which interpretation was correct, each interpretation was acceptable.

The generalization participants should develop is that the meaning of a text is the result of the knowledge readers use to interpret it. The very same passage can be interpreted differently depending upon the knowledge readers bring to it.

School texts are written to convey a common body of knowledge to students. With most school reading assignments, particularly in science, students are not suppose to interpret a text just from their own perspective or experience. Instead, teachers have a particular interpretation they want students to achieve so that they learn the facts, concepts, and generalizations of science.

Refer the participants back to the passage and ask if both interpretations would be valid if the title "A Night of Music" had preceded the passage. Discuss with them how that title constrained or limited the type of interpretation a proficient reader should achieve. Point out that much of learning how to read science materials involves teaching students how to confine their interpretations to the information presented and how to interpret science passages in ways the writers intended.

By this time, participants should understand that students with little prior knowledge about music would probably make very little sense out of the passage even if they knew the title. Obviously, for those students a teacher would help them develop some notion about musical notes, tempo, musical arrangements, musical equipment, etc. Such instruction would help students create a mental framework for understanding. With any reading assignment, such instruction is needed. Students will use their personal knowledge and experience to interpret assigned readings unless the teacher helps them create a particular mental framework and purpose for reading. Without such guidance, students may interpret the assigned readings in ways quite different from the one a teacher and/or writer intended. In that sense, the students prior knowledge could impede, rather than facilitate comprehension.

Have participants discuss personal experiences when they have misinterpreted texts or examples of when their students' prior knowledge may have interferred with comprehension. Some of the points in the article by Eaton, Anderson, and Smith (1984) might help the workshop leader guide this discussion.

C. Summarize with participants the key generalizations discussed.

(1) The meaning of any text depends upon the knowledge readers employ to process it and understand it.

(2) Students will use what they know to try and understand reading assignments. This may impede, rather than facilitate, student learning from science texts unless the teacher has carefully helped students develop the appropriate mental framework to guide their understanding of science reading assignments.

5. If necessary, summarize the key generalizations about the nature of reading processes each of the passages was used to illustrate. These might be listed on the board or an overhead.

6. Link this activity with Activity 2. Explain to participants that to effectively use a textbook, teachers need to understand how the knowledge and experience of their students influences reading performance. However, the way textbook passages are written can also influence student understanding and learning. Discuss with them differences in science texts used at different grade levels. They should bring out points, such as, texts for younger students have easier words and sentences, etc. Suggest that no textbook will ever be written perfectly so that all students at a given grade level can read and learn from them without guidance. Nevertheless, research findings show that how texts are written can also greatly affect student learning. Reading involves using what writers say, as well as information one already knows. And it is the interaction between the words of the authors and the prior knowledge of students that produces comprehension. Comprehension cannot occur, however, if a text is poorly written or written in ways that are inappropriate for a particular group of students.

   The purpose of the next activity is to train participants in techniques for analyzing passages from student textbooks.

REFERENCES

This article is especially recommended to the leader.

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PASSAGE 1: A MARDSAN GIBERTER FOR FARFIE

Glis was very fraper. She had denarpen Farfie's mardsan. She didn't talp a giberter for him. So she conlanted to plimp a mardsan binky for him. She had just sparved the binky when he jibbed in the gorger.

"Clorsty Mardsan!" She boffed.

"That's a croustish mardsan binky," boffed Farfie, "but my mardsan is on Stansan. Agasan is Kelsan."

"In that ruspen," boffed Glis, "I won't whank you your giberter until Stansan."

QUESTION: What is the title of the passage?

____

PASSAGE 2

The procedure is actually quite simple. First, you arrange things into different groups. Of course, one pile may be sufficient, depending on how much there is to do. If you have to go somewhere else, due to lack of facilities, that is the next step. Otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than to do too many. In the short run, this may not seem important; but complications can easily arise. A mistake can be expensive as well. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one never can tell. After the procedure is completed, one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually, they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

a. List the steps involved in carrying out the procedure.

b. Why might you have to go somewhere else?

c. Why is it important not to overdo things?

d. How does the procedure eventually change?

e. Why should one arrange the materials in different groups?

f. What is the title of the paragraph?

PASSAGE 3

With hocked gems financing him, our hero bravely defied all scornful laughter that tried to prevent his scheme. Your eyes deceive you, he had said; an egg, not a table, correctly typifies this unexplored planet. Now three sturdy sisters sought proof, forging along sometimes through calm vastness, yet more often over turbulent peaks and valleys. Days became weeks as many doubters spread fearful rumors about the edge. At last, from nowhere, welcome winged creatures appeared, signifying momentous success.

QUESTION: What is the title of this passage?

PASSAGE 4

Every Saturday night, four good friends get together. When Jerry, Mike, and Pat arrived, Karen was sitting in her living room writing some notes. She quickly gathered the cards and stood up to greet her friends at the door. They followed her into the living room; but, as usual, they couldn't agree on exactly what to play. Jerry eventually took a stand and set things up. Finally, they began to play. Karen's recorder filled the room with soft and pleasant music. Early in the evening, Mike noticed Pat's hand and the many diamonds. As the night progressed, the tempo of play increased. Finally, a lull in the activities occurred. Taking advantage of this, Jerry pondered the arrangement in front of him. Mike interrupted Jerry's reverie and said, "Let's hear the score." They listened carefully and commented on their performance. When the comments were all heard, Karen's friends, exhausted but happy, went home.

QUESTION: What did the four people comment on?

a. The odds of having so many high cards
b. The sound of their music
c. The high cost of musical instruments
d. How well they were playing cards

Teaching Aid 4

ACTIVITY 2: PROCEDURES FOR ANALYZING TEXTS

The purpose of this activity is for teachers (1) to understand that the clarity of explanations and explicitness of relationships among ideas are better guides to estimating the difficulty of textbooks than readability formulas, and (2) to acquire skill in analyzing passages from textbooks to determine if they are clearly structured, coherent, unified, and appropriate for students in the elementary grades.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The primary role of the workshop leader in this activity is to explain and demonstrate to participants features of writing that can affect student learning. A direct instructional model should be employed in which the leader explains and demonstrates key concepts and skills to be acquired, guides and monitors practice, and provides feedback to participants. Thus, this activity will begin with explanation and demonstration followed by whole and small group practice in analyzing passages from textbooks. The workshop leader's behavior in summary form is listed below:

1. Present three passages for teachers to analyze and evaluate.
    A. Guide discussion of participants' reactions to the passages clarifying the limitations of readability formulas for estimating the difficulty of written material.
    B. Explain and demonstrate why the passages are or are not appropriate for learning new information.
    C. Define and provide examples of text characteristics that influence student comprehension and learning. Key concepts to be developed relate to:
        (1) Text structure
        (2) Coherence
        (3) Unity
        (4) Audience appropriateness
    D. Summarize the steps for evaluating reading selections.
2. Divide participants into groups to practice analyzing texts according to the criteria developed in the first part of the workshop.
    A. Provide members of each group with passages to be analyzed and clear directions as to what the group is to do.

B. Monitor the progess of the groups, clarifying key points and providing corrective feedback.

C. Guide whole group discussion about the small group evaluations of the passages and summarize the major points made about characteristics of texts that influence student learning.

MATERIALS LIST

Twenty(20) copies of each of the passages to be analyzed. The workshop leader might want to have transparencies of each passage, also, as a way to focus participants' attention to the text characteristics discussed.

ADVANCE PREPARATION

As with the preceding activity, the key to preparing for this activity is for workshop leaders to understand themselves the concepts and skills to be presented. A brief summary of key ideas and points to be made is presented below; however, the workshop leaders are encouraged to read some of the articles listed at the end of the summary.

SUMMARY/DISCUSSION

The goal of science instruction is to help students develop and understand the concepts and principles of science. A textbook, just like a microscope, is one tool that can be used to achieve this goal. Textbooks, particularly science texts, should be designed to inform students about ideas that are new to them. Because of this, science textbooks should have more complex vocabulary and sentence structures than basal reading materials and should not be used without instructional guidance. This means that teachers need skills in evaluating materials they assign during science instruction so that they can guide student understanding. Teachers also need to be able to examine the passages to determine (1) if they are suitable for supporting science learning, and (2) where students might encounter difficulty as they read.

Science textbooks may present major obstacles to learning because of the very nature of the information they are designed to convey. At one level, they are to inform students about science facts, concepts and principles that were discovered by others in the past. This information comprises the body of knowledge that makes science a distinct field of study. Nevertheless, because many of the facts, concepts, and generalizations in science texts are part of the accumulated wisdom of the field, it is easy to assume that students can read the ideas of others and automatically understand them.

Students can indeed rote memorize scientific information about such things as force, gravity, or magnetism; but until they can use the information to classify, explain or predict phenomena, a teacher cannot be sure that the students understand what they read. More importantly, the teacher cannot be sure the facts, concepts, and generalizations read have become facts, concepts, and generalizations in the students' own minds.

This aspect of reading is intricately tied to the other level at which science texts present obstacles to learning. These texts are not only designed to present information, but are also designed to help students acquire the patterns of thinking and reasoning that undergird the field. In some ways the language of science has its own grammar and forms of discussion. As an example, the term velocity can be defined as how fast a body is moving and the direction in which it is moving. Students must learn how to interpret such a definition as a mathematical statement about how to measure speed, not to treat it as a way to characterize some vague notion about speed (Kurland, 1985). That is, students must learn to think in terms of the information presented in science texts--how the information can be used--not just to think about what the information is.

Unfortunately, many science textbooks are not necessarily written so that students can learn from them. Science is an especially difficult area because of the tremendous number of new terms and concepts introduced within a given passage or chapter. Science texts present more terms more rapidly than any other subject-matter texts, and these new terms label highly complex and abstract concepts that may not match the students' common sense knowledge of how the world works. (For example, how many people really think of the world as being made of atoms, cells, molecules, etc.?) If the information in textbooks is not sufficiently explained and described, students are almost forced to rote memorize it because they cannot understand it.

This is a particular problem in textbooks developed for science instruction in the elementary grades. Publishers have felt pressed to write these books to suit some readability formula. Readability formulas are used to estimate the grade-level suitability of a text based on an average of the number of short/long sentences, as well as the average number of easy/difficult words (usually easy is equated with short words and difficult with long words). While there are some valid uses for these formulas, using them as a guide to writing textbooks is not one of them. Nevertheless, the practice persists and results in textbooks that are poorly written. Key words that tie ideas together are omitted, to decrease the length of sentences: insufficient information is presented to decrease the length of reading passages, and words that label key concepts are avoided.

A readability formula is included in the appendix to this activity. It might be useful to workshop leaders who are unfamiliar with these formulas to try to use it with a science text. That would ensure the leaders understood what the formulas measure. Otherwise, it is not recommended that copies of the formula be distributed to workshop participants.

TEACHING SEQUENCE

1. Tell the participants that this activity is designed to illustrate that science passages written to conform to a readability formula may be quite difficult to comprehend. Just because a passage has short sentences, easy words, and aids to the pronunciation of new words does not mean that the information in the passage will be easy to learn.

    A. Distribute copies of Passage 1 and Passage 2. Ask participants to read them to determine which passage would be more difficult for intermediate-grade students to read.

    B. After they have read the passages, ask volunteers to state which passage they felt was more difficult and why. Accept all responses.

        (1) Ask what learning goal would teachers have in mind when they assigned a passage like this to students? Guide the discussion so that most participants agree that the goal would probably have something to do with students learning about the structure, location, and function of the heart. Given that goal, ask which passage would most help students to understand something about the structure, location and function of the heart.

        Participants should see that there is insufficient information in the first passage for students to learn much about the relationships among the location, structure and function of the heart. The information is too abstract for students who may have never studied how the heart works. For example, students could not understand from Passage 1 how the location and structure of the right atrium and right ventricle is related to their function (sending blood to the lungs vs. the rest of the body).

        (2) Discuss with participants how Passage 1 might seem easier for students to read, but there is not much they could learn or understand from reading it. Explain that this type writing is typical of texts written according to a readability formula. Key points to focus on are that:

(a) Short sentences and words do not cause ideas to be easy or hard to learn.

(b) Guides to word pronunciation do not help students acquire an understanding of what the words mean.

(c) Short sentences and passages may impede student learning in that they promote word calling and shallow levels of comprehension.

(3) Distribute Passage 3, "What a Cell is Like." Ask participants to read the passage to determine what students could learn from it and why they might encounter difficulty. Participants should note that the phrase "living stuff" is too vague. They also might comment on the fact that the general term "stuff" was used to describe a cell but more technical terms like "oxygen" and "stimuli" also are used in the passage. Point out that if the students could not understand a more technical definition of a cell, then they would certainly have trouble with the terms oxygen and stimuli. Reinforce the notion that shorter words and sentences do not make ideas easier to learn.

C. Explain to participants that the primary function of a textbook is to inform students about things they do not already know. To do so, the chapters and passages in texts must have sufficient information in them for students to understand the concepts and generalizations presented. That means there is enough information provided in the passage that students can determine how the ideas are related. Moreover, the information must be at a level of abstraction appropriate to the age and background knowledge of the students. Words like "stuff," however, are probably not appropriate for students at any age.

Explain to participants that there are qualitative aspects of writing that need to be evaluated to determine if a passage or chapter is suitable for instruction. This type of analysis is supported by research findings which suggest that certain characteristics of writing greatly influence ways students process and understand what they read. Tell the participants that you are going to focus on four features of writing that they should look for when analyzing reading assignments.

Listed below are definitions and explanations about the four aspects of writing. For each one, you should present a definition, example, and how to examine a passage to identify it. The examples are drawn from the passages already used in this activity.

(1) Text Structure - the pattern or system a writer uses to arrange ideas in a text and the way in which ideas are connected or related. The author's purpose determines the pattern used. For example, authors may write to explain, describe, define, etc. If the purpose is to explain a process, then the ideas might be arranged in sequence or cause-effect pattern.

Most science textbooks follow an expository pattern which consists of:

(a) Introductory paragraphs at the beginning of chapters, articles or selections.

(b) The body of the text which may be organized in any of the following patterns:

-Definition
-Illustration
-Comparison/Contrast Relations
-Problem/Solution Relations
-Chronological Order
-Superordinate/Subordinate Relations (Main Idea/Detail)

(c) Transitional paragraphs

(d) Enumeration, discussion or summary paragraphs

A textbook writer's structure should be clear to both teachers and students from titles, headings, topic sentences, or introductory paragraphs. Thus, to determine if a selection is well structured, teachers should try to create an outline of the ideas to be presented by reading only the titles, headings, and introductory sentences in the selection.

One reason texts need to be structured well is because readers can learn to use authors' structures to organize ideas in their own minds. If participants have difficulty with the concept of structure, contrast an expository structure with a story structure. Ideas in stories are organized into a setting and episodes, or a plot outline. In the setting, characters are introduced and background information is provided (e.g., where the story takes place). In an episode, some sort of conflict is introduced, the characters' response(s) to the conflict are revealed, their attempts to resolve it described, and some sort of conclusion or resolution presented. Have participants recall a common fairy tale, such as "Little Red Riding Hood." Point out that they recalled events and information in the same order as a plot outline. Knowing the structure of stories helped them understand and remember the fairy tale, just as knowing how a textbook writer structured information in a passage can help students understand and remember what they read.

Refer participants to Passage 2. This is an example of a well structured passage because the relationships among ideas are explicit, and the most important idea is stated in the first sentence. The passage then describes how the heart pumps blood.

(2) Coherence - refers to the logical flow of ideas, how well the ideas "stick together." A selection is coherent if the relationships among ideas are explicitly stated, references are clear and the order of events flow in a logical or sequential manner.

The more unfamiliar the material to be read is to students or the lower their reading ability, the more important it is that authors explicitly signal how the ideas should be related. Examples of common signal words are:

(a) WHAT, WHO, WHY, WHEN, WHICH, DO, CAN, WILL, etc. These words frequently start a sentence and signal a possible question/answer relationship.

(b) AND signals additional information or connection.

(c) OR signals an alternative relationship.

(d) FIRST, NEXT, WHILE, LATER, AFTERWARDS, FINALLY, etc., signal a sequence or chronological relationship.

(e) BECAUSE, IN ORDER TO, SINCE, WHEN, SO THAT, THEREFORE, IF, etc., signal a cause and effect relationship.

(f) ALTHOUGH, BUT, HOWEVER, YET, ON THE OTHER HAND, etc., signal a contrast or opposite relationship.

(g) MEANS THAT, IS CALLED, THAT IS, FOR EXAMPLE, TYPE OF, SUCH AS, FOR INSTANCE, etc., signal a definition or that the ideas that follow are examples.

A common problem in many elementary texts is that the words to which pronouns refer are not clear. This breaks the flow of meaning and can cause comprehension problems. Another problem relates to sequences and/or processes and explanations. In a coherent text, the order of events should proceed in one direction only. Thus, to examine the coherence of a passage, teachers should determine if:

(h) The relationships among ideas are explicitly stated.

(i) Pronoun references are clear.

(j) Sequences and explanations are logical and proceed in one direction only.

Refer participants to Passage 3. The pronoun "it" in the second and third sentences is incoherent. Is the "it" referring to "cell" or "living stuff?"

(3) Unity - refers to a text having focus and addressing one purpose or topic. A unified text does not include irrelevant or distracting information that leads readers away from the major points an author wants the readers to grasp. Obviously, to determine if a text has unity, teachers should examine it for irrelevant and distracting information.

Refer participants to Passages 1 and 2. In Passage 1, the sentence "Right and left refer to the body's right and left sides," is potentially distracting. The point is for students to understand that the right atrium and ventricle differ from the left atrium and ventricle in function--not that they differ because of the sides of the body on which they are located. Passage 2 handles this point more effectively by signaling to the reader that this is a minor point by placing the information in parentheses.

(4) Audience Appropriateness - refers to how suitable the passage is in terms of the prior knowledge of the readers. Most of the words should be understandable to intermediate grade students, and technical terms should be carefully defined and thoroughly explained. Moreover, the text should have sufficient information in it so that students with little prior knowledge about the topic can learn from the selection.

To examine a passage for audience appropriateness, teachers must first of all know their students and have some sense of what they have learned about the topic in the past. The selection should then be examined to determine if the level of vocabulary is appropriate for those students, technical vocabulary is clearly defined, and sufficient information is provided for students to learn new ideas.

Refer participants to Passage 1. This passage is inappropriate for intermediate grade students as it is too abstract. There simply is insufficient information provided for students to learn about the structure and function of the heart. For older or more knowledgeable students, the passage might be appropriate. For students to whom the information is new, however, the text would be meaningless.

D. Summarize and repeat the steps for evaluating reading selections. The workshop leader might want to prepare a teaching aid listing the steps or present them on an overhead. These ideas may still be fuzzy to participants, so explain that you will go through another passage with them as a group before expecting them to work on their own. The characteristics of texts to be evaluated and questions to raise are summarized below.

(1) Text Structure - Does the selection have a clear structure and purpose? Can an outline of the major ideas to be presented be developed by reading:

  (a) titles
  (b) headings
  (c) introductory sentences and/or paragraphs

(2) Coherence - Is there a logical flow among the ideas within and between paragraphs?

  (a) Are the relationships among ideas explicit?
  (b) Are pronoun and other references clear?
  (c) Do sequences and/or explanations proceed in one direction only?

(3) Unity - Does the selection address a single purpose or topic?

  (a) Is any of the information irrelevant?
  (b) Is any of the information distracting?

(4) Audience Appropriateness - Is the text suited to the age and ability level of the students?

  (a) Is the vocabulary too difficult?

(b) Are the technical terms clearly defined and thoroughly explained?
(c) Is there sufficient information in the passage for students to learn ideas that are new to them?

2. Tell the participants that the purpose of this activity is to provide them with guided practice in applying the ideas discussed in the previous activity. All participants will examine a passage together before they are divided into small groups for additional practice and feedback.

   A. Distribute Passage 4. Ask the participants to read it silently and then to evaluate the text in terms of how suitable it would be for intermediate grade students who are learning about the human body. Caution teachers to try not to fill in ideas from their own information actually stated by the author of the passage. They are to evaluate the passage for structure, coherence, unity, and audience appropriateness.

      (1) After they have finished reading the passage, ask for volunteers to present their evaluations. Deal with one text characteristic at a time.

      (2) The major problem with this passage is that it is poorly structured. The title implies that the passage will explain how nerves carry signals. Instead, the passage simply describes the parts of nerve cells. Note that the passage does not say anywhere how electrical charges originate or how a message/signal gets from the axon of one cell to the dendrite of another. As a description of nerve cells, the passage is otherwise coherent, unified, and appropriate for intermediate grade students.

   B. Divide the participants in small groups and distribute the remainder of the passages. Depending on the time available, the workshop leader might want to distribute only a few of the passages for analysis. Or, the leader might assign different passages to each group. The material in Passages 6A and 6B and Passages 8A and 8B are two versions of the same information, and participants should decide which is more appropriate for intermediate students.

      One member of each group needs to act as a recorder and to present the group's responses to the rest of the participants in the discussion which is to follow the small group activity.

      The workshop leader should monitor the small group discussions, intervening to clarify points or make suggestions.

C. When the groups have completed their analyses, the workshop leader should guide a discussion in which the group responses are compared.

Each passage may have good as well as poor writing characteristics, but each has at least one major flaw. The major problems with each passage are listed below.

(1) Passage 5 - The major problem with this passage is one of unity. The implied purpose from the title suggests that the passage will describe Dutch settlement in America. Therefore, the information in the third paragraph about the hunting abilities of Indians is irrelevant and detracts from the topic.

Another problem with the passage is one of coherence. In the second paragraph, the sentence, "They wanted to make money, too," has an unclear referent. Nowhere in the first paragraph is the goal of making money linked with new settlements, yet the word "too" suggests that some mention has been made previously of other settlers wanting to make money. Note how paragraph three makes the relationship between making money and trading furs hard to follow.

(2) Passage 6 - The major problem with this passage is again one of unity. The implied purpose of the paragraph is to describe how tobacco became a crop. The last sentence is irrelevant.

(3) Passage 7 - The temporal sequence in this passage is out of order. Thus, the passage is not coherent. In sentences 1-3, the order of events is all right. Sentence 4 then reverts back to the time when the baby alligators are still in the shell: sentence 5 leaps to when they are old enough to leave the nest; and sentence 6 talks about when they are first hatched.

(4) Passage 8 - This passage explains a process, but the phases or cycles described are again out of order. Thus, this passage also has a major coherence problem. Note how the sentences skip from morning to evening processes. It would have been better to talk about all of the events that occur during the evening in one paragraph, then to describe the events that occur during the morning in a second paragraph.

This passage also has some unclear references. Does the word "amount" in sentence 5 refer to sugar or carbon dioxide?

(5) Passage 9 - The major problem with Passage 9A is also one of coherence. Signal or connective words that indicate the relationships among ideas are missing. Participants should have noted that the relationship between the price of land and owning a farm is made explicit in Passage 9B as is the relationship between the forests and the cost of raising hogs.

(6) Passage 10 - Obviously, the major problem in this passage relates to pronoun reference. The passage is incoherent because the nouns to which the words "they," "many," and "some" refer are not clear.

(7) Passage 11 - Passage 11A would be most appropriate for intermediate grade students. Participants should note how technical vocabulary that is unnecessary is avoided, yet the same information is conveyed without confusing students with too much detail. Passage 11B is not poorly written; it is simply inappropriate for intermediate grade students.

(8) Passage 12 - Passage 12 is inappropriate for intermediate grade students because it assumes too much prior knowledge about how matter changes from one form to another and, therefore, is incomplete. Participants should note that "matter" is never defined and the passage and questions in the passage would be incoherent to most students. The causes of condensation and evaporation are not stated, and the relationship of these processes to fog, steam on windows, and humidity is never explained. It is simply left up to the student to figure out.

References

Listed below are some articles that elaborate on the ideas discussed above. Unless indicated, all of the textbook examples were taken from the articles by Anderson and Armbruster (1984 & 1986).

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PASSAGE 1

A human heart is a cone-shaped, muscular organ about the size of a large fist. The heart is located in the center of the chest behind the breastbone and between the lungs.

A human heart contains four chambers--right atrium (AY tree uhm), left atrium, right ventricle (VEN trih kuhl), and left ventricle. Right and left refer to the body's right and left sides. A wall separates the chambers on the right from the chambers on the left.

Anderson, R., Hiebert, E., Scott, J. & Wilkinson, I. (1985). Becoming a Nation of Readers: The Report of the Commission on Reading. Washington, D.C.: The National Institute of Education.

Teaching Aid 1

PASSAGE 2

The heart is a part of the circulatory system that pumps blood throughout the body. The heart is located in the center of the chest behind the breastbone and between the lungs. The human heart is suited for pumping because it is a hollow, cone-shaped, muscular organ about the size of a large fist. Being hollow, the heart can easily fill up with blood. Once filled, the heart muscle provides the power necessary for pumping the blood through the body.

A human heart contains four hollow chambers made for receiving and sending blood. The right atrium (AY tree uhm) and right ventricle (VEN trih kuhl) receive and send blood to the lungs, while the left atrium and left ventricle receive and send blood to the rest of the body. (Note that right and left refer to your body's right-hand and left-hand sides.) The right and left sides of the heart are separated by a wall of muscle. This wall keeps blood going to the lungs separate from the blood going to the body.

Anderson, R., Hiebert, E., Scott, J. & Wilkinson, I. (1985). *Becoming a Nation of Readers: The Report of the Commission on Reading*. Washington, D.C.: The National Institute of Education.

PASSAGE 3

A cell is made of living stuff. It can grow. It takes in food and changes the food into more living stuff. A cell combines food and oxygen to make energy for all the things it does. The living stuff in a cell responds to stimuli. It moves.

PASSAGE 4: HOW DO NERVES CARRY SIGNALS?

Each nerve in the body is really a bundle of very fine nerve fibers. Nerve fibers are too thin to be seen except with a microscope. Each nerve fiber is part of a nerve cell.

dendrite
branch of a nerve that carries impulses to the nerve cell body

The nerve cell has a very irregular shape. It has a number of small branches sticking out, almost like the branches on a tree. These are called dendrites (den' drit). The word dendrite comes from a Greek word for "tree."

axon
a long nerve fiber that carries impulses away from the nerve cell body

At one end of the cell is a particularly long branch. It is called an axon. This axon is a single nerve fiber, as shown in the drawing.

The message that travels along the nerve cell is a small electrical charge. It usually starts at the dendrites, goes through the cell body, and then moves out along the axon. This electrical charge is called the nerve impulse.

synapse
a small gap between nerve cells

Nerve cells are strung together in chains. The branches of the axon of one cell come close to the dendrites of another cell. The parts of the different cells don't quite touch. There is a small gap between them that is called a synapse (si' naps).

PASSAGE 5: THE DUTCH COME TO AMERICA

Other Europeans came to America besides the Virginia colonists and the Pilgrims. The French traded and settled along the St. Lawrence River in Canada. Spain had colonies in the far south. Other European countries were claiming land and sending settlers, too.

Dutch merchants in the Netherlands started a company. They wanted to make money, too. The Dutch colony sent people to the New World. The people built a fort on a large island in the Hudson River. They called it Fort Manhattan (man HAT n).

Many Indians lived near Fort Manhattan. Indians were good hunters and trappers. They knew how to find wild animals in the forests. When an Indian shot an arrow, he hardly ever missed. If he did, he might have to go to bed without his supper.

The Indians caught animals for their beautiful, soft furs. The Dutch wanted the furs to sell in Europe. The Dutch traded many things with the Indians. Fort Manhattan became the center for Dutch fur trade.

PASSAGE 6: TOBACCO

The Indians grew tobacco which they smoked in pipes. Smoking was probably brought to England in the late 1500's. It quickly became popular. Historians were not sure who brought tobacco to England. Some think it was Sir Walter Raleigh. (He named Virginia in honor of Queen Elizabeth, "the Virgin Queen.")

PASSAGE 7

1. Adult female alligators make large cone-shaped nests from mud and compost. 2. The female lays from 15 to 100 eggs with leathery shells in the nest and then covers it. 3. The heat from both the sun and the decaying compost keeps the eggs warm. 4. The eggs hatch in about nine weeks. 5. Unlike other reptiles that hatch from eggs, baby alligators make sounds while they are still in the shell. 6. The mother then bites off the nest so the baby alligators can get out. When first hatched, baby alligators are about 15 to 25 cm. long.

PASSAGE 8

1. Photosynthesis in the leaves starts with the morning sunlight. 2. Carbon dioxide was made during respiration all night. 3. It was stored in the air spaces around the spongy cells. 4. This carbon dioxide is used as the leaf starts to make sugar. 5. When a certain amount has been used up, the guard cells respond. 6. They become stiff, swell out, and make openings in the leaf. 7. They stay open all day. 8. In the evening, the light fades. 9. Photosynthesis slows down. 10. But, respiration goes on. 11. The amount of carbon dioxide in the air spaces builds up again. 12. This buildup of carbon dioxide makes the guard cells relax. 13. The openings are closed.

PASSAGE 9A

Many farmers who moved in from New England were independent farmers. Land cost about a dollar an acre. Most men could afford to set up their own farms. Livestock farming was quite common on the frontier. Hogs could be fed in the forests. The cost of raising hogs was low.

PASSAGE 9B

Most of the farmers who moved in from New England were independent farmers. Being an independent farmer means that the farmer can afford to own his own farm. Around 1815, most men could afford to own their own farms because land was cheap--it cost only about a dollar an acre. Many of these independent farms were livestock farms. For example, many frontier farmers raised hogs. Hog farming was common because hogs were inexpensive to keep. The cost of raising hogs was low because the farmer did not have to buy special feed for the hogs. The hogs did not need special feed because they could eat plants that grew in the surrounding forests.

PASSAGE 10: WHY WOMEN SHOULD NOT VOTE

"A woman's place is in the home!" many men said. Politics would have a bad effect on women's characters, they said. Women would soon be neglecting their homes.

Many also said that women's voting would cause arguments in the family. Arguments would weaken the family. Some believed that women were inferior to men by nature. They said that men were physically stronger and more intelligent than women. They said that women were too emotional. They were too excitable to vote wisely.

Many people attacked the women who were working for suffrage. They said that they were unattractive. They said that they were unhappily married and only wanted attention.

PASSAGE 11A: STRUCTURE OF THE LEAF

Suppose you magnified a small square patch of a green leaf. The top surface of a leaf is made up of a thin layer of tough cells. These cells protect the softer cells inside the leaf. This is what your own skin cells do. The tough ones on top protect the cells deeper down inside you. Beneath the tough surface cells in the leaf is a layer of cells. These long cells have a rich supply of chlorophyll. It is the substance that makes green plants green.

When you pick up a leaf and look at it, all parts of the leaf seem to be equally green. But suppose you looked at a thin slice under a microscope. You would see that most of the chlorophyll is sandwiched in the middle layers of the leaf.

Just below the layer of long cells is a loose layer of cells. These cells also have lots of chlorophyll. Notice the air spaces among these loosely-packed cells. They make this layer look like a sponge. So they are called spongy cells.

If you followed one of the air passageways, you would see that it leads to an opening in the lower layer of tough cells. These openings let gases from the air get inside the leaf. And they let gases made by the green cells flow out of the leaf.

PASSAGE 11B: STRUCTURE OF THE LEAF

A microscopic examination of a leaf cut crosswise reveals five major regions: upper epidermis, lower epidermis, veins, palisade region, and spongy region.

1. Upper epidermis. The upper epidermis of the leaf consists of a single layer of cells. These cells secrete a waxy protective coating.

2. Lower epidermis. Except for the many pairs of guard cells, the cells of the lower epidermis are much like those of the upper epidermis. A stomate, or pore, lies between each pair of guard cells. The guard cells regulate the size of the pore.

3. Veins. Veins are composed mainly of xylem and phloem tubes, which are connected to the xylem and phloem of the stem and root.

4. Palisade region. The palisade region, which lies just below the upper epidermis, consists of one or more layers of elongated, box-like cells. Each cell contains numerous chloroplasts, the bodies that bear chlorophyll. Most of the food of a plant is made in the palisade region.

5. Spongy region. The spongy region lies between the palisade layer and the lower epidermis. The cells of the spongy region are somewhat rounded and loosely arranged. These cells also contain chloroplasts and carry on some food-making. Large air spaces are scattered among the cells. The air spaces lead to the stomates.

PASSAGE 12: A CHANGE OF PHASE

Solids, liquids, and gases are phases, or forms of matter. Matter sometimes changes from one phase to another. Some matter can again change to the phase in which it first was. When this happens, matter changes phases in a cycle.

Water Comes Out of the Air

Water changes phases in a cycle. In one part of the cycle, water comes out of air. It condenses, or changes from a gas to a liquid. Many things make water condense.

Look at each of these pictures. (The accompanying three pictures are of a glass of ice water, a girl with mouth partially open, and a storm.) Look for evidence that water has changed from a gas to a liquid.

Why do you think that the water condensed?
Why do windows in your home sometimes steam up?
What can make a city by the sea foggy?

Water Goes Into Air

In one part of the water cycle, water condenses. It comes out of air. In the other part of the cycle, water goes into the air. It evaporates, or changes from a liquid to a gas. Many things make water evaporate.

Look at each of these pictures. (The accompanying three pictures are of waves breaking on a beach, steam coming from a teakettle, and haze or fog along a road.) Look for evidence that water has changed from a liquid to a gas.

Why did the water evaporate?
What do you think makes it humid on hot days?
What happens when wet clothes dry?

ACTIVITY 3: ANALYSIS OF A PASSAGE FROM A SCIENCE TEXT

In this activity participants will apply the techniques and concepts discussed in previous activities to evaluate a passage from a science text. They will read and evaluate a chapter from a fourth-grade textbook to determine (1) if the text is structured, coherent, unified, and appropriate to a fourth-grade audience, and (2) how the passage might be best used to support student learning of concepts and generalizations related to magnets. Participants will also be asked to assess the suggestions for teaching the chapter in terms of the influence of prior knowledge on comprehension, and they will be asked to examine the instructional activities designed to guide and assess student learning.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The major responsibility of the workshop leader in this activity is to monitor participants' analysis of the chapter and to guide a discussion in which they compare the results of their analysis. Specifically, the workshop leader will:

1. Distribute the chapter and give instructions for analyzing it.
2. Monitor and guide participants as they examine the chapter.
3. Guide a group discussion in which participants share the results of their analysis of the chapter.

MATERIALS LIST

One copy of Unit 8, Chapter One, "Magnets," (Appendix A) and paper for each participant to record his/her observations and criticisms of the chapter.

ADVANCE PREPARATION

The workshop leader should analyze the passage, teaching suggestions and student activities. While suggestions for analyzing the teaching activities are discussed below, the workshop leader may want to add to these suggestions. A key to the success of this activity is to make sure that participants view the passage from the perspective of a fourth-grade student and not fill in information from their own prior knowledge and experience.

Any reading activity involves interpretation. Thus, the responses of teachers should vary to some degree. The aim of this activity is to have participants think about the characteristics of writing that can influence student reading performance, as well as how those characteristics could affect students who have varying degrees of prior knowledge about magnets.

TEACHING SEQUENCE

1. Distribute copies of the chapter. Ask teachers to evaluate the suggestions for teaching the chapter, the passage, and the learning activities in the chapter for guiding and assessing student understanding.

   A. To analyze the teaching suggestions, have participants answer questions such as the following:

      (1) Are the suggestions for introducing the chapter explicit?

         (a) Assessing students' prior knowledge about the topic?

         (b) Preteaching key concepts and technical vocabulary?

         (c) Setting purposes for reading?

         (d) Relating the information to students' prior knowledge and experience?

      (2) When suggestions to discuss ideas with students are made, are explicit suggestions given as to ways to focus and guide the discussion?

      (3) Is technical information sufficiently explained so that teachers would know which concepts and generalizations in the passage are most important?

      (4) Are their suggestions for focusing students' attention on diagrams and/or illustrations? Do the suggestions specify what students should note or observe in the diagrams/illustrations?

      (5) Are the suggested student responses or suggested answers appropriate? That is, do the questions and responses reflect conceptual understanding or rote recall of facts?

      (6) Are their suggestions for adapting instruction for students of varying reading ability?

   B. To analyze the passage, use the questions summarized at the end of Activity 2, Section 1D.

   C. To analyze the instructional activities, have participants answer questions like those listed below:

      (1) Are there questions embedded in the passage to assess student understanding while they are reading?

(2) Do the questions in the passage or suggested questions in the teacher's guide assess understanding of concepts and generalizations, as well as facts?

(a) Fact questions usually require students to locate, recognize, or remember information directly/explicitly stated in the passage.

(b) A good way to determine if students are acquiring concepts is to have them classify information. Asking for definitions, matching terms with definitions, or having students use words in sentences is not a clear guage of conceptual understanding. Each of these tasks could require rote memory only.

(3) Can the questions be answered, given the information directly stated or easily inferred from reading the passage?

(4) Do the answers to the questions imbedded in the passage help students clarify the significance of the information they are reading?

2. Have individuals work alone or in small groups to analyze the chapter. Monitor their progress and clarify any questions they might have.

3. When most of the participants have completed their analysis, guide a discussion of their responses and reasons for their responses.

Suggested problems with this chapter are listed below.

A. Strengths and Weaknesses of the suggestions for teaching the chapter.

(1) Suggestions for introducing the unit on magnets and electricity focus on electricity only.

(2) No suggestions are provided for preteaching vocabulary or new concepts. Moreover, there are no guidelines for guiding the discussion which is to introduce the chapter. It is not clear what students are to note in the picture, nor are there any suggestions for ways to establish students' prior knowledge about, or experience with, magnets. The authors simply assume the students have had some prior experience.

(3) There is insufficient technical information with each lesson to explain to teachers which concepts and generalizations in the passages are most important.

(4) No suggestions are provided for teachers who do not have magnets available for use in their classes.

(5) Most of the answers to the questions in the text require only that students either locate specific information or rotely recall statements from the passage. Suggestion 6 in the first lesson is a good example of this problem. The suggested answer reflects memory for a specific fact, not a conceptual understanding of why the nail became magnetized.

(6) There are suggestions for varying a science experiment for students of different ability levels, but not suggestions for ways to vary instruction for students who differ in reading skill.

(7) Numerous concrete experiments are suggested which could be employed quite easily in most classes.

B. Strengths and Weaknesses of the Passage

(1) There are two major problems associated with the information in the first lesson. First, the pictures provide only marginal support for gaining some insight into magnets. For example, the picture of the lodestone can't show magnetic properties as explicity as having a lodestone to show students would. Moreover, the information in the passage fails to relate the picture to the information presented about lodestones.

A second major problem has to do with structure. The passage describes three types of magnets (natural, permanent, and temporary), yet how the three are alike or different is made explicit only for permanent and temporary magnets. The significance of talking about lodestones is never made clear, and this information really seems irrelevant to the topic because it is not elaborated.

Other problems that might be noted:

(a) Common terms with technical meanings in science are used in the passage. For example, the word "attract" is used in the definition for magnets, but the meaning of "attract" is not discussed until the next lesson.

(b) The writers assume that students know the meaning of particles and properties, yet they do not define the terms "permanent" and "temporary" in any detail.

(2) Somehow it seems that the information in lesson two should have preceded lesson one, a problem of structure. Given the order that is actually presented, lesson two also has a major problem with structure in that the significance of magnetic force and magnetic fields is not explained in sufficient detail for a novice to comprehend. Students would have to have very vivid imaginations to imagine the feel of a magnetic force or the effect of a magnetic field.

Other problems that might be noted with this section are:

(a) The paragraph on page 259 that precedes the heading "Some Uses of Magnets" lacks explicit statements about the relationship between the pattern of iron filings and the end of the pattern at the surface of the magnet.

(b) The last sentence of that same paragraph presents irrelevant or distracting information. What is the significance of the magnetic field going through the magnet?

(3) The major problem with information in the final lesson is one of coherence. The relationhip between use of a compass and magnets is unclear and never explicitly addressed anywhere in the chapter. Moreover, the writers assume the students know how to use a compass to find directions.

In the next papagraph, the relationship between the shape of a horseshoe magnet, small spaces, and toy cars is not made explicit. Nor is the relationship between the size of an industry and the uses of magnets in industry made explicit. The invited inference is that large industries use large magnets to separate large pieces of metal, while small ("other") industries use small magnets to pick up small pieces of metal.

Without more detail and explanation, the information about the uses of magnets would be meaningless to students who did not have a great deal of prior knowldge about magnets and how they are used.

(4) A major strength of the chapter as a whole is that the vocabulary level in general seems quite appropriate for fourth-grade students. The major problem with the chapter as a whole is one of audience appropriateness. There is insufficient explanation provided for students to understand the concepts (magnet force, magnetic field, etc.) and the generalizations (unlike magnetic poles attract each other, like poles repel) simply by

reading and talking about the ideas in the passage. Unless some of the suggested experiments were carried out, the chapter would be meaningless to many students.

C. Strengths and weaknesses of the student activities.

(1) Questions are imbedded or interspersed throughout the chapter. However, most of the questions can be answered simply by locating specific sentences or rotely recalling the information. This can be illustrated by noting the acceptable responses provided in the teaching guide.

(2) Some of the interspersed questions cannot be answered by information in the passage. For example, in Lesson 1, the questions at the end of the section on "Making a Magnet" could not be answered unless the students had actually magnetized an object.

(3) The questions under "What did you learn?" in the activity section do not lead students to relate the results of the experiment/activity back to the concept of magnetic field. However, the questions under "Using what you learned" would be quite good if the students also had to explain why they made the predictions.

(4) In the review section, the suggestion to have students make posters seems like busy work. A more fruitful activity would be to have them write a summary or create an outline of the major ideas from the passage.

Moreover, the suggestion to have students design a word search puzzle is busy work. The tasks require memory of how the words are spelled or just plain copying skill, not a conceptual understanding of what the words mean. And, most of the questions in this section could quite easily be answered rotely or by locating specific sentences in the passage with words that matched those used in the questions.

(5) While some of the review questions on the text master (located in Appendix A, page 261A) review basic facts, concepts, and generalizations, some of the questions require students to remember information that was not emphasized or clarified in the body of the passage. For example, why is the north pole of a magnet called "north-seeking," or why should students remember the names of metals that can be magnetized when those metals were mentioned only once in the passage?

> The enrichment activity is irrelevant. The task does not provide practice in using the concepts from the passage to classify, compare or contrast. The activity is simply a spelling review of words that were not central to the meaning of the paasage or to understanding the concepts "magnet" or "magnetism."
>
> Questions 3, 4, and 8 on the test require more than just factual recall. Question 3 requires that students compare and contrast two types of magnets, which is a good gauge of conceptual understanding. Question 4 might involve some degree of application which would show that students grasped the generalization about unlike poles attracting and like poles repelling each other, and question 8 could show some understanding of the concept of a magnetic field. The question could be improved by requiring students to explain why their drawing depicts a magnetic field. Other questions on the test require memory for basic facts from the passage, except for question 5. The answer to this question was never explicitly addressed in the passage. The only way students might be able to answer this question is if they had conducted some of the activities suggested.

As previously noted, responses might vary depending upon each teacher's own personal experience and interpretation of the material. Nevertheless, the discussion should bring out clearly the point that for most students, the concrete experiences with magnets suggested in the teaching guide should precede their reading of the passage. For example, the activity for finding a magnetic field should be experienced, rather than talked about, for students to truly grasp to any degree that concept. For most students, the primary use of this passage should be to reinforce and summarize information they gained from working and interacting with magnets. The next activity is designed to provide teachers with a procedure for helping students use the concepts and generalizations gained through science activities to elaborate and make sense out of information in science reading material. Such an approach would reinforce students' understanding of science information, as well as teach them how to use what they have learned to make sense out of printed material.

ACTIVITY 4: GUIDING READING ASSIGNMENTS

The aim of this activity is to introduce teachers to an instructional strategy for guiding science reading assignments. The procedure is a variation of an approach used in most basal reading materials, so teachers will be involved in discussing how the strategy compares to one they currently employ. A key objective of the activity is for teachers to develop a framework for planning science lessons in which reading assignments are used (1) to elaborate and reinforce what students learn through science activities and experiments, and (2) to train students in strategies for comprehending science textbooks. If time permits, teachers will also observe a demonstration of the instructional strategy.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

In this activity, the workshop leader will introduce an instructional strategy for guiding student reading assignments. Since the approach should not be totally new to most elementary school teachers, the leader should engage participants in discussions about ways the strategy is similar to, or different from, one they already employ. The workshop leader might model/demonstrate the strategy if time permits. Otherwise, the leader should guide discussion of possible ways the strategy could be applied in a classroom setting. In summary form the workshop leader will:

1. Present the major components of a directed reading-thinking activity (DRTA) as an instructional strategy that can be used with science textbooks.
2. Guide discussions about how the DRTA is similar to, or different from, the approach used with basal reading lessons.
3. Guide discussion about ways in which the strategy could be applied in a classroom setting, or demonstrate and model the strategy.

MATERIALS LIST

No additional materials are needed for this activity, unless the workshop leader wants to develop a handout which lists the components of a directed reading-thinking activity. Otherwise, the chapter on magnets used in the previous activity should serve as a resource for modeling or discussing the instructional strategy introduced.

ADVANCE PREPARATION

Workshop leaders need to understand the components of a DRTA and how the procedure is similar to, or different from, a typical basal reading lesson. One way to develop this understanding is to study a teacher's manual that accompanies a basal reader. But, in general, such lessons are divided into three phases or components. Prior to reading, teachers are to discuss with students events in their lives that are related to the events in the story they will read, preteach vocabulary, and set a purpose for reading. Students in the second phase are supposed to read the story or segments of the story silently. Then, in the last phase, the teacher checks to determine if students met their purpose for reading, guides re-reading of segments to correct comprehension errors or detect word identification problems, and provides some type of enrichment or extended learning activity.

In most basal reading lessons, the purposes are set by the teacher, and the approach is teacher dominated. Thus, the focus is on teacher questioning and students responding with "correct" answers. A DRTA differs in that the focus is on the reading process and on teaching students how to develop their own purposes for reading in which they make predictions and then read to confirm/disconfirm them. The DRTA involves more interaction and discussion between students and the teacher, and the teacher acts more like a guide than a lecturer or presenter of information.

The DRTA procedure is described in most content-area or elementary reading methods texts. Some of these should be consulted by workshop leaders who are not familiar with the approach. The article by Guerra (1984) is also a good resource and directly ties that strategy to reading in science. The only other preparation required for this activity is for the leader to find places in the chapter on magnets that could be used to demonstrate the procedure or components of it, if time allows.

TEACHING SEQUENCE

1. Ask teachers to describe how they usually teach lessons in their basal readers. List the steps they describe on the board or an overhead. Then suggest to the participants that many of the same instructional activities should occur whenever students are asked to read content material. Perhaps, these activities are even more important because much of the information in content texts is new. Explain to participants that you are going to describe a strategy that can be used which integrates science experiments and activities with science reading assignments. The procedure is called a directed-reading thinking activity and involves three major phases.

    A. Phase One: Any of the science experiments discussed in other workshop sessions could be used at this phase. The objective is to preteach science facts, concepts, and generalizations through science activities and experiments. This step is crucial to students acquiring the knowledge or mental framework they need to understand or interpret science passages.

Technical vocabulary should be introduced and used during the activities or in discussions about what students learned through the activities.

B. Phase Two: This phase involves directing the reading-thinking process and involves the reader in three steps: predicting, reading, and proving. As students proceed through a selection, they predict or define purposes for reading; they read and select relevant data; and they evaluate and revise predictions using information they acquire. These processes mirror the information processing strategies that should be developed through science experiments (see Topic 3).

(1) When teachers introduce the DRTA, they should first familiarize students with a strategy for dealing with unknown words (words they cannot pronounce--the meaning of technical vocabulary should have already been taught). If students encounter unknown words, they are to implement the following steps in the specified order:

(a) Read to the end of the sentence.
(b) Use picture clues, if available.
(c) Sound out the word.
(d) Ask the teacher for help.

(2) Each student should either receive or locate a copy of the selection; the teacher then directs students to study the titles, headings, pictures/diagrams, or topic sentences on the first page. Teachers should ask questions that lead students to make predictions about what information will be included in the selection they are to read. Sample questions are:

(a) What do you think a passage with this title (heading, picture) might be about?
(b) What information do you think will be discussed in this section?

(c) Do other class members agree or disagree with this prediction? Why or why not?

The teacher should encourage students to make several different suggestions and to discuss agreement or disagreement with one another's suggestions. The teacher serves as a guide to students interacting with each other.

(3) The teacher should direct the students to read a segment of the selection silently to check their predictions. The teacher would be responsible for ensuring that students read for meaning, observing reading performance, and helping students who request help with words. When the latter occurs, the teacher might have the student suggest a word

that might fit; or, if the word is still not recognized, the teacher should pronounce it for the student.

The silent reading phase allows teachers to vary the procedure for students of varying reading levels. Students with poor reading skills should be asked to read smaller segments of the passage before responding to questions. By varying the amount of information different students read and respond to, the teacher can use the same text with an entire class, while providing special instruction to students who have reading difficulties.

(4) After students have read the first segment, the teacher should ask them to close their book; and the comprehension check would begin.

Questions should guide students to examine the evidence found in the passage which confirms or disconfirms their predictions.

(a) "Were you correct?" or "What do you think now?" lead students to examine the proof of their predictions. Students should be asked to orally read particular sentences or segments that they feel confirmed or disconfirmed their prediction.

(b) "What do you think now?" or "What do you think will be explained next?" could lead students to screen their ideas and to make predictions about information to come.

(5) The students should make new predictions, then silently read the next segment of the text. With each new segment of reading material, the students would continue the predicting, reading, and proving cycle.

C. Phase Three: This phase involves skill training. Students might be asked to re-examine segments of the assignment, partic-lar words or phrases, and pictures or diagrams for the purpose of developing their reading-thinking abilities. Instruction might focus on word identification strategies, concept clarification, reasoning skills, and/or reflective abilities. The format of these activities would vary, but, in many cases, would be similar to the suggested exercises in the teacher's guide, the workbooks or the skillbooks that accompany most science texts.

2. Guide discussion about how the procedure is similar to, or different from, the approach used with basal reading material. Point out to participants that as students use titles, headings, pictures, and topic sentences to make predictions, they are also learning how to

identify and use the author's organizational structure to guide their reading. Moreover, as students encounter technical words they cannot pronounce, the teacher can ask them to recall the science activity or experiment to see if they can remember a word that would fit the context of the text segment they are reading. Allow participants to make other suggestions about how the approach can be a modified plan of a typical reading lesson.

3. If time permits, select a lesson from the chapter on magnets and demonstrate how teachers might use the approach. The demonstration should focus on leading students to use what they learned in science activities to make predictions and to elaborate on what they have learned. If time is not available, summarize the steps of the procedure and discuss ways it could be applied in a classroom.

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Tierney, R., Readance, I. & Dishner, E. (1980). Reading strategies and practices: A guide for improving instruction. Boston, Allyn and Bacon, Inc., 1980.

Topic 7. ACQUISITION AND MANAGEMENT OF ELEMENTARY SCHOOL SCIENCE MATERIALS

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Elementary school teachers face many problems in doing their job. These run the gamut from low salaries to claasroom management. Included among the problems related to instruction is the perennial concern about obtaining necessary instructional equipment and supplies. Because of inadequate sources of funds, many elementary school teachers are unable to provide children with direct experiences using commercially-available materials that are often costly. This becomes a particularly important factor when the subject matter is science. Research in science education has shown us repeatedly that key concepts in the sciences are learned best by most elementary school children when direct experiences addressing the concepts are provided for the children. Faced with fiscal reality on one hand and the need to provide "hands-on" activities on the other, the elementary school science teacher must adopt innovative strategies to meet equipment and supply needs. Some of these tried-and-true "strategies" include sophisticated begging, improvising, pack-ratting, and scrounging. The purpose of this topic is to help workshop participants become better beggars, improvisers, pack-rats, and scroungers by providing them with information about materials needed for an elementary school science program, free and inexpensive materials, community sources of science supplies, and efficient storage of science supplies. A listing of commercial suppliers of science materials and a bibliography of sources of ideas for science activities are also provided. Many of these are identified as "supplements," which can be found at the end of this topic.

Activities developed for this topic focus on using readily available materials in innovative ways to teach science concepts. Workshop participants are also instructed in the use of science supply catalogs and activity source books. As the workshop leader, it is your responsibility to formulate a training session that would be most beneficial for the elementary school science teachers in your school district. When preparing a program from this particular topic, we suggest that you begin by making enough copies of the supplements at the end of the topic for all participants in the workshop. (These supplements could serve as the impetus for a good idea-sharing session that would enhance the remainder of the workshop program.) Then select those activities which you feel are most appropriate for your situation. For example, time constraints may make it necessary for you to include in your workshop presentation only two or three of the demonstrations from Activity 2. During all the activities, stimulation of creative thinking and ingenuity on the part of participants should be your goal.

Activity 1: PARDON ME, BUT YOUR INGENUITY IS SHOWING!

The purpose of this activity is to allow individuals to explore as many ways as possible to use common materials in teaching science. Since the activity is very open-ended, your role should be one of facilitating interaction within groups and among groups. Some groups may have difficulty getting started. If the difficulty seems substantial, you may consider suggesting to the group one of the ideas mentioned below. This strategy may provide the spark needed to get the group going.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Discuss the purpose of the activity with workshop participants.

2. Divide participants into groups of four. Provide instructions for the participants concerning how to complete the activity.

3. Circulate among participant groups as they do the activity. Answer questions as necessary and provide "moral support."

4. Involve participant groups in sharing the ideas for activities that they have formulated. The activities presented should be analyzed in terms of content and process.

MATERIALS LIST

For each group of four participants:

One Zip-Loc bag containing a toothpick
1 paper clip
1 rubber band
1 bean seed
1 paper towel
1 book or box of matches
1 soda straw
1 balloon
1 pill vial
1 marble

ADVANCE PREPARATION

Assemble one set of the materials listed above for each anticipated participant group. Zip-Loc bags are recommended to reduce the possibility of spillage. Have a larger quantity of each of the items listed on hand should the participants request additional materials.

TEACHING SEQUENCE

1. Organize participants into small groups of four individuals each. Distribute one bag containing the items mentioned above to each group.

2. Give instructions for completing the activity. The instructions might be worded something like this:

> "Each group is to select a leader and recorder. Your group will be allowed ten minutes to brainstorm and record as many ideas for hands-on science activities as possible to teach content and processes with the materials provided. You may assume adequate quantities of these items to be available for any activity you devise. In addition, you may assume the classroom has basic furnishings, water, air, light, and other environmental components commonly present. At the end of the brainstorming session, each group's recorder will share the ideas generated in that group with the rest of us. We will analyze these ideas in terms of content to be taught and process skills that will be utilized."

Participants may include the Zip-Loc bag as part of the materials with which they have to work.

3. During the brainstorming session, circulate among participant groups. Answer any questions that might arise. If a group has significant difficulty in beginning the activity, you might suggest one of the following ideas as an example of how some of the materials could be used.

   (a) Students could develop their own system of measurement using one of the items as the standard by which the other items are measured. For example, the dimensions of the other objects could be measured in terms of paper-clip length. This could be successful in teaching about the degree of confusion that would arise if everybody used different standards for measurement.

   (b) Set up a germination study by folding the paper towel and moistening it with water. Put the bean seed between the towel folds and place this in the Zip Loc bag. Expose the system to warmth by placing it on a window sill.

   (c) Investigate sinking and floating behavior of several objects. Fill the pill vial with water. Have students predict whether the following materials will sink or float: small piece of toothpick, bean seed, small piece of paper towel, portion of match, marble.

   (d) Have students show that force is a two-way proposition by filling the balloon with air, then releasing it. The balloon will shoot through the room until all the air is expelled. The action of the air rushing out of the balloon produces an equal reaction in the opposite direction-- the forward motion of the balloon.

(e) Students can explore an important characteristic of light by filling the pill vial about 3/4 full with water and adding the soda straw. They will observe that the straw appears larger in diameter. This is due to the fact that light rays bend when they move on a slant through transparent substances of different densities (the water and the plastic).

(f) Prepare a Cartesian diver system to investigate pressure relationships. Cut a section from the balloon large enough to cover the top of the pill vial. Fill the pill bottle with water. Cut off a small segment of a small, wooden safety match. This segment should include the head and a small portion of the wood behind the head. You may need to experiment a little to determine the proper length required. Place the match segment in the pill vial. Stretch the portion of balloon over the top of the pill vial and secure it tightly with the rubber band. Using your finger, slowly apply pressure to the balloon. The match segment will begin to sink. When pressure on the balloon is released, the match segment will rise.

4. After ten minutes, ask each group reporter to present the ideas generated in his or her group to all the participants. Examine the ideas for creative use of the materials, involvement in various processes of science, number of topics that could be taught, and total number of suggestions that emerged. The participants will usually develop a number of good ideas if they are in the least bit creative and/or imaginative.

Activity 2: DOING SCIENCE ON THE THINNEST OF SHOESTRINGS

To continue promoting the innovative use of readily available and inexpensive items in teaching hands-on science, this activity consists of demonstrations that you will perform for workshop participants. When you read the steps in the teaching sequence for each demonstration you will note that, in many instances, the procedure described or the equipment constructed could be used in numerous classroom activities designed to teach a particular concept. This was our intention. At the conclusion of each demonstration, it is the responsibility of the participants, under your leadership, to develop more specific ideas as to the range of classroom activities in which the procedure or equipment could be used. We have included some suggested applications with each demonstration.

DEMONSTRATION 1: GASSED-UP AND READY TO GO

Discussed somewhere in the curriculum of most elementary school science programs are the physical states of matter. When describing the characteristics (properties) of gases, one of these states of matter, we are sometimes limited to using air as the exclusive example due to its easy accessibility, the fact that children are familiar with it, and the unavailability of other gases. Comparing air with other gases during hands-on activities would, however, be helpful in pointing out to students that even though gases have similar general properties, their specific properties can vary quite a bit. The demonstration described below addresses this problem by allowing you to show workshop participants a cheap and easy method of preparing carbon dioxide and oxygen.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Provide participants with an overview of the demonstration that will be done.

2. Select a volunteer to lend assistance and then conduct the demonstration. Since this is a demonstration, it is obviously very important to describe each step in the procedure to the participants.

3. Lead participants in a discussion of the theory behind the reactions and specific ways in which this could be used in the classroom.

MATERIALS LIST

For one demonstration:

1 ounce of hydrogen peroxide
1/8 teaspoon of dry yeast
2 twist ties
1 quart freezer bag (not Zip-Loc)
1 twelve-inch piece of aquarium tubing
3 large pill vials (Clear plastic ones, rather than colored plastic ones, are best.)
1 wooden splint
1 large plastic container (Clear plastic is best.) to serve as the water reservoir, matches, paper towels

ADVANCE PREPARATION

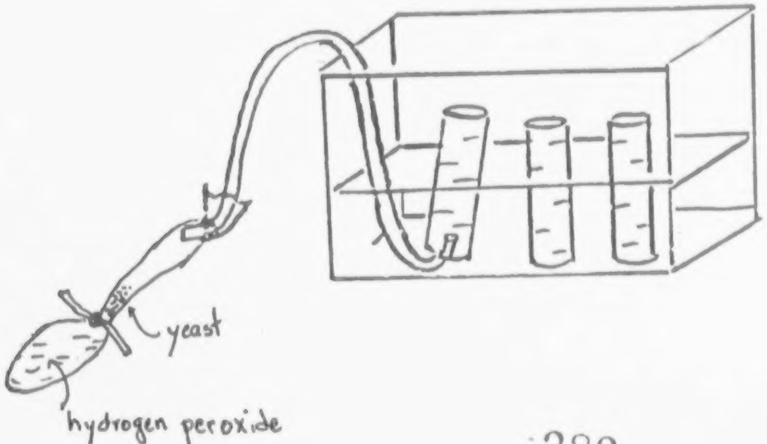
Assemble all materials needed for the demonstration. If a large, clear plastic container is used as the water reservoir, participants will be able to see the plastic vials filling with gas more easily. It may not be necessary to use the entire length of aquarium tubing.

TEACHING SEQUENCE

1. Provide an overview of the demonstration. You may wish to pattern your comments along the lines of those given above.

2. Conduct the demonstration as described below:

   (a) Place 1 ounce of hydrogen peroxide inside the plastic bag. When pouring the hydrogen peroxide, avoid dribbling it down the inside of the bag.
   (b) About 2 inches above the hydrogen peroxide, tie the bag tightly with the twist tie. Place 1/8 teaspoon of dry yeast in the bag.
   (c) Carefully press as much air as possible out of the bag.
   (d) Insert one end of the aquarium tubing into the mouth of the bag to a depth of about two inches. Do not allow yeast to get into the tubing.
   (e) Fasten the bag securely around the aquarium tubing with a twist tie making sure the system is air tight. Put the system aside.
   (f) Fill the large plastic container about 3/4 full of water. Fill three pill vials with water and invert each in the container of water. Should air bubbles enter the pill vials, refill the vials. (A vial can be filled efficiently by adding water until the vial overflows, placing a hand over the mouth of the vial, quickly inverting the vial, and putting the vial in the water container so that the mouth of the vial is below the surface of the water in the water container.) Your assistant could be responsible for working with the vials after they have been filled and placed in the water reservoir.
   (g) Insert the aquarium tubing extending from the plastic bag into the mouth of an inverted pill vial. The completed system should look like the illustration which appears below.



(h) Remove the twist tie that separates the yeast from the hydrogen peroxide and mix the two substances.

(i) Gently squeeze the plastic bag to force the gas into the pill vial. Since the gas produced is less dense than water, it will replace the water that is present in the inverted pill vials. This method of collecting gases is known as water displacement. (The presence of gas bubbles, along with a decreasing water level in the vials as they fill, is evidence that the reaction is proceeding normally.)

(j) When a vial is filled, remove the aquarium tubing from its mouth and place the tube in the mouth of the next vial to be filled. Your assistant will be helpful in stabilizing the vials during this process.

(k) After the vials have been filled, make a statement and ask a question similar to the following:

> "We have just collected oxygen gas by a process called water displacement. Now that we have the gas, what possible uses could we make of it in the classroom?"

3. Lead participants in a discussion of the theory behind the reactions and specific ways in which this could be used in the classroom.

DEMONSTRATION 2: MAKING THE CURRENT FLOW FOR JUST A LITTLE DOUGH

The study of electrivity and electric circuits can be an exciting experience for children. It can become more practical from a budgetary standpoint by using homemade equipment. This demonstration will include suggestions for making holders for a D cell (flashlight "battery") and a small (flashlight) bulb.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Provide participants with an overview of the demonstration that will be done.

2. Conduct the demonstration. The demonstrations should be performed in the order presented below, since the D cell holder is used when testing the bulb holder.

3. Involve participants in discussing the demonstration.

MATERIALS LIST

For one demonstration of how to make a D cell holder:

- 2 brass paper fasteners
- 1 wide rubber band (¼" wide x 2-2½" long)
- bell wire
- 1 D cell
- 1 knife

For one demonstration of how to make a flashlight bulb holder:

- 1 jumbo paper clip
- 3/4" wide masking tape
- 1 flashlight bulb with screw-type base
- scissors

ADVANCE PREPARATION

Assemble all materials needed for the demonstration. You may wish to cut two 1-foot lengths of bell wire. When purchasing materials, make sure that the flashlight bulbs have a screw-type base. Most other bulbs will not properly fit the paper clip. Use 1½ volt bulbs.

TEACHING SEQUENCE

1. Provide an overview of the demonstration. You may wish to pattern your comments along the lines of those given above.

2. Conduct the demonstration as follows:

Making a D Cell Holder

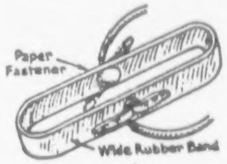
(a) If not already done, cut two 1-foot lengths of bell wire.

(b) Strip about 1½ inches of insulation from each end of the two wires. If the insulation is of the lacquered-type, it can be scraped from the wire using the knife. Thicker insulation should be removed by cutting it down to the wire and then pulling the insulation off.

(c) Take 1 length of wire and wrap the end from which the insulation has been removed around one of the brass paper fasteners. The wire should be positioned as close to the head of the fastener as possible. Repeat the process using the other section of wire and the other paper fastener.

(d) Press one fastener/wire combination through each end of the rubber band.

(e) Spread the fastener apart so that the attached wire is pressed firmly against the head of the fastener. The completed D cell holder should look like the illustration shown below.



(f) Show participants the correct method for insuring proper contact between the D cell and the brass fasteners. The rubber band should be stretched over the D cell in such a fashion that the head of one brass fastener makes contact with the raised portion on the top of the D cell, while the other brass fastener makes contact with the bottom of the D cell.

(g) Tell participants that the D cell holders should not be left in place when the D cells are not being used. To do so would result in the D cells becoming "worn out" by short circuits.

Making a Bulb Holder

(a) Make a statement to participants similar to the following:

> "Now that we have a reliable way of tapping our energy source, we can use the energy to light a bulb. However, to do this we need some way to make proper contact with the bulb. This can be easily accomplished by connecting our D cell assembly to a homemade bulb holder containing a flashlight bulb."

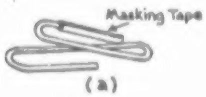
(b) Take a jumbo paper clip and spread it slightly apart so that one arm of the paper clip extends above the other arm.

(c) Cut a short piece of masking tape and wrap it around one section of the small arm of the paper clip. See illustration "a" below.

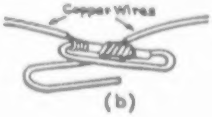
(d) Obtain the D cell holder that you made earlier. Tightly wrap the bare portion of one of the wires around the masking tape that was applied to the paper clip. Next, tightly wind the bare end of the other wire around the paper clip as close to the masking tape as possible. See illustration "b" below.

(e) Turn the paper clip over and screw a flashlight bulb into the large arm of the paper clip. Make sure the tip of the bulb touches the wire around the tape. (The long arm of the paper clip may have to be bent to allow proper contact.) See illustration "c" below.

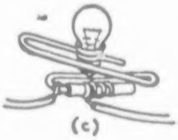
(f) If all connections have been properly made, the bulb will light.



(a)



(b)



(c)

3. Involve participants in discussing the demonstration.

DEMONSTRATION 3: TESTING PROPERTIES OF SUBSTANCES

A good activity involving use of the process skills termed observing, classifying, and making inferences is the study of properties of common substances. The activity given below allows students to investigate what happens when five substances are exposed to heat, water, iodine solution, and vinegar. Interpretation of each of these tests will allow students to effectively separate one substance from the other, based on its properties.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Provide participants with an overview of the demonstration that will be done.

2. Arrange participants into small groups and supply each group with a set of white powders along with a hand lense for observations.

3. Demonstrate by performing four tests on each of the four powders.

4. Answer questions from participants and encourage discussion.

MATERIALS LIST

For each group of participants: 5 small paper cups containing small amounts of sugar, corn starch, salt, baking soda, and plaster of Paris; hand lenses (one for each member of the group).

Your materials for the demonstration portion of the activity: small paper cups containing sugar, corn starch, salt, baking soda, and plaster of Paris; supply of small cups; stirring sticks; 5 aluminum foil cups; wooden spring clothespins; candle; matches; water; small container of vinegar; iodine solution; medicine droppers.

ADVANCE PREPARATION

Assemble all materials needed for the activity. The "iodine solution" referred to in the activity is actually a crystalline iodine and potassium iodide dissolved in water. This solution is available from commercial supply houses as "Lugol's solution." It is poisonous, so appropriate precautions should be taken.

TEACHING SEQUENCE

1. Inform participants that they will be involved in investigating properties of substances and in using these properties to distinguish one substance from another.

2. Organize participants into small groups and provide each group with a set of powders and hand lenses. Write the following question on the blackboard: "Using the materials available to you, what observations can you make about these 'powders'?" Allow five minutes for each group to generate observations. Ask that each group leader report the observations made by the group members. Write the observations on the blackboard.

3. After summarizing the observations made about the "powders," ask: "How could we separate these substances from each other?" (Answer: These substances can be differentiated based upon their properties.) Tell participants that you have selected four tests to perform on each of the white powders. These tests will allow you to investigate four properties of each of the substances: response to heat, water, vinegar, and iodine solution. By examining these properties, you will be able to get a better idea of the identity of each substance.

   Test each powder using heat, water, vinegar, and iodine solution. Record the results of each test in a summary table on the blackboard. The suggested table format is:

	heat	water	vinegar	iodine
powder #1				
powder #2				
powder #3				
powder #4				
powder #5				

4. Based upon observations made during the earlier part of the activity and properties investigated during the latter part of the activity, ask participants to tentatively identify each of the powders. Have participants discuss modifications that could be made in the activity to fit their particular classroom situations.

Activity 3: IF I ONLY HAD SOME MONEY!

Many elementary schools periodically receive catalogs from various suppliers of science materials. Unfortunately, for many of us the catalogs more often than not serve only as wishbooks with teachers who peruse them uttering statements like "If I only had some money!" Let's escape reality for a moment and assume that you did have "a little green" to spend on science supplies. To get the most for the limited funds available, planning is the key. For example, it makes little sense to purchase materials from science supply companies that could be easily obtained locally at a substantially lower cost or perhaps at no cost. But, in terms of planning, the cart is already ahead of the horse. Before you can determine which supplies are best obtained locally you need to prepare a master list of supplies needed to teach the science program in your school (or at least at the grade level you teach). Obviously, the science equipment and supplies needed by an elementary school will depend upon the kind of science program that is used in the school. Most elementary schools in Mississippi have science programs that are built around a single textbook series. Consequently, a list of materials needed for the experiments and other activities described in the books will constitute the materials list for the program. Preparation of such a list probably seems like a monstrous endeavor; however, help is available since many textbook publishers have already prepared such lists and will mail them to schools upon request. If you can't get a list and don't have time to prepare one, you'll find some help in Supplement A, a generic list of equipment and supplies usually needed in active, on-going elementary science programs. For convenience, the equipment and supplies are combined and listed alphabetically under appropriate science topics.

Whatever the source of the list, start paring it down by first investigating local businesses. As mentioned earlier, an item obtained locally is usually cheaper than the equivalent item ordered from a science supply company. Supplement B contains a partial listing of places in the community that could be sources of supplies for a science program in the elementary school.

Before picking up the pen and catalog order form, explore another veritable gold mine of supplies--household garbage. Many of the things that you throw away on a regular basis can become important supplies in the science classroom. Start collecting materials now. Save everything that you think could even be remotely used during science instruction. Pack-ratting is necessary since it is difficult to accumulate large quantities of certain items in a short time. You will find that Supplement C will help you become a more discriminating pack-rat.

When all else fails, pull out the science supply catalog. Those items that still have not been checked off your list will probably have to be ordered. Supplement D includes a list of science suppliers, their addresses, tollfree numbers (when available), and a general description of the kinds of science supplies carried by the company. Careful attention is necessary to avoid mistakes in ordering. Since each catalog lists different sizes and qualities of the same article, it is necessary to know the exact use for which the article is intended. For clarity in ordering, you must include the name of the item together with any special characteristics such as size and dimensions, the quantity desired, the catalog number of the item, and the cost.

The activity which follows will provide some practical experience in ordering materials from scientific supply houses.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Provide an overview concerning acquisition of supplies for elementary school science teaching. Use the material furnished previously as the basis for your remarks. Make sure you mention the supplements at the end of this topic as important information sources.

2. Organize workshop participants for group work. The size of the groups will likely be dictated by the number of catalogs available.

3. Distribute requisition sheets. Instruct participants about the task to be performed. Answer questions. Allow 30 minutes for completion of the activity.

4. Have groups check each other's work. Summarize the activity by asking appropriate questions.

MATERIALS LIST

For each group of five participants:

1 copy of five different science supply company catalogs
school district requisition sheets

ADVANCE PREPARATION

Obtain materials needed for the activity. If enough catalogs are not available, make a request to the junior high school and high school in your school district for loan of a few science supply catalogs. Individual science suppliers listed in Supplement D may be contacted directly to obtain catalogs. When making a request for multiple copies of a company's catalog, you should describe the type workshop that will be conducted and indicate specifically how the catalogs will be used. Furnishing this information in your letter (on school letterhead) will improve the chances that the company will honor your request. Allow ample time for receipt of catalogs from companies (4-6 weeks).

Requisition forms used in your school district should be used during the activity. This will allow you to point out any special procedures that must be followed when ordering science supplies for the school district.

Since Activity 4 included in this topic also makes use of materials that may be in short supply in your school district, you may wish to consider having some participant groups complete Activity 3 while others do Activity 4. Groups could exchange materials after a prescribed length of time so that all participants would eventually complete both activities.

Prepare a mini-lecture on materials acquisition for elementary school science teaching using the information provided on the preceding pages. Since acquisition of adequate and appropriate materials is a major concern when using a hands-on approach to science, don't short-change the mini-lecture by rushing into the manupulative aspect of this activity.

TEACHING SEQUENCE

1. Distribute a copy of supplements A - E to each participant. Present your mini-lecture concerning acquisition of science materials.

2. Organize the participants by forming several groups containing five individuals per group.

3. Provide instructions similar to the following:

> "Your principal has found a surplus of $300 in the instructional supplies budget. Since you've recently been giving him a hard time about needing more science equipment, he decides to shut you up by giving you the money. The only stipulation is that your order contain the following: six 250 ml beakers, two 100 ml graduated cylinders, six Celsius thermometers, 12 hand lenses, red and blue litmus paper, 500 ml of Lugol's solution, 1 balance (scale), and 2 newton spring scales. You may select additional items, but the total order cannot exceed $300. Each person in your group is to prepare a separate order. Write down problems or questions as they occur, so that you can share them with other groups during our summary time."

Circulate among the groups as they proceed through the activity. Make a note of each question that you answer so that you can share them with all groups during the summary time. Allow approximately 30 minutes for the activity.

4. Lead participants in checking their requisitions for completeness. Information needed on the requisition for proper order processing by the company includes catalog numbers, quantities, descriptions, and prices of the items.

   Summarize the activity by asking participants to share with the group some of the questions they had or some of the problems they experienced in using the catalogs. Finally, ask participants to suggest criteria for selecting elementary school science supplies and equipment. List these on the blackboard. The criteria might include: durability, cost, ease of reading graduations (if the item is a measuring instrument), and number of uses for which the item is suitable.

ACTIVITY 7.4: INVESTIGATING SCIENCE TOPICS USING RESOURCE MATERIALS

This activity is designed to familiarize workshop participants with currently available books and periodicals which include hands-on science investigations for elementary school children. Participants will be asked to familiarize themselves with these materials by researching specific topics assigned to them. The activity will culminate with reporting of findings by each participant group.

DIRECTION FOR THE WORKSHOP LEADER: SUMMARY

1. Inform participants of the purpose of the activity (see above).

2. Organize participants for group work.

3. Assign a topic to each group and allow them to work on it for 30 minutes to an hour.

4. After the prescribed period of time, ask each group to report their findings.

MATERIALS LIST

For each group of five participants: activity resource books, science methods books (see Supplement E), and back issues of "Science and Children".

ADVANCE PREPARATION

Obtain materials needed for the activity. Copies of the activity resource books and science methods books appearing in Supplement E should be ordered from the publishers. Addresses of the publishers can be found in the current edition of Books in Print. Allow ample time for receipt of books from publishers (4-6 weeks). Back issues of the magazine "Science and Children" may be obtained from: National Science Teachers Association, 1742 Connecticut Ave., N.W., Washington, D.C. 20009.

Since Activity 3 included in this topic also makes use of materials that may be in short supply in your school district, you may wish to consider having some participant groups complete Activity 3 while others do Activity 4. Groups could exchange materials after a prescribed length of time so that all participants would eventually complete both activities.

TEACHING SEQUENCE

1. Organize the participants by forming several groups containing five individuals per group. (Group size may vary depending on the number of resources available for use.)

2. Provide instructions similar to the following:

   > "We're going to investigate some resources in which can be found science activities appropriate for elementary school children. These activities could be used to supplement material in the textbook or could serve as the basis for class projects. I will assign each group a particular science topic to research for 30 minutes using the resource materials. I would like for you to locate some hands-on activities that could be used with elementary school children. Record the source, page number, and one-line description of each activity that you find. At the end of the prescribed time period, I will ask each group leader to share the group's findings."

3. Assign each group one of these nine topics: life cycles, air pressure, evaporation and condensation, states of matter, chemical reactions, characteristics of light, temperature measurement, magnetic interactions, current electricity.

   Allow 30 minutes to an hour for group interaction.

4. After the prescribed time period, ask each group leader to report their findings. Encourage discussion of the ideas that are presented.

SUPPLEMENT A
Equipment and Supplies for Elementary School Science

Air and Weather

Anemometer
Barometer, aneroid
Fan, electric
Hygrometer, wet and dry
Rain gauge
Tubes, barometer
Weather forecast indicator

Animals

Aquarium cages
Aquarium
Dip nets
Insect cages
Insect nets
Wire mesh, ½ inch
Wire screen

Astronomy

Balls, assorted
Flashligh
Globe, terrestrial
Lamp, gooseneck
Planetarium, inexpensive
Telescope and tripod

Chemicals

Alcohol, denatured or wood
Ammonia
Baking soda (sodium bicarbonate)
Boric acid
Copper sulfate, crystals
Food coloring, assorted
Hydrochloric acid, dilute
Hydrogen peroxide, 3%
Iodine, tincture
Lemon juice (acetic acid)
Limewater (calcium hydroxide)
Litmus paper, red and blue
Manganese dioxide
Mercury, metal
Nitric acid, dilute
Paraffin
Plaster of Paris
Salt, table
Splints, wood
Starch
Sulfur, powdered
Sulfuric acid, dilute
Vinegar
Washing soda (sodium carbonate)

Cork and Rubber

Balloons, rubber
Dam, rubber
Stoppers, cork, assorted
Stopper, rubber, solid
Stoppers, rubber, one-hole
Stoppers, rubber, two-hole
Tubing, plastic, assorted
Tubing, rubber, assorted

Electricity

Bell, electric
Buzzer, electric
Copper strips, 1 in. x 4 in.
Copper wire, insulated, #18 or #20
Generator, electric, hand-powered
Motor, St. Louis type
Porcelain sockets, screw

Copper wire, insulated, #28
Switches, knife
Dry cells, #6
Flashlight and batteries
Flashlight bulbs, screw base, 1½ and 3 volts
base for flashlight bulb
Fuses
Switches, push button
Zinc strips, 1" x 4"

Glassware

Beakers, Pyrex, assorted
Cylinders, graduated, assorted
Droppers, medicine
Evaporating dishes, porcelain
Flasks, Erlenmeyer, assorted
Flasks, Florence, assorted
Thistle tube
Funnels, short stem
Jars, battery
Rods, assorted thicknesses
Test tubes, Pyrex, assorted
Tubing, assorted widths

Heat, Fire, and Fuels

Alcohol burner
Asbestos mat
Ball-and-ring apparatus
Boiler, double
Candles
Canned heat (Sterno)
Chimneys, lamp
Compound bar apparatus
Convection box
Hot plate, electric
Matches, safety
Tea kettle
Thermometer, clinical
Thermometer, Celsius
Thermometer, Fahrenheit
Thermometer, outside
Wire, copper
Gas burner, portable

Ironware and General Supplies

Filter paper, assorted sizes
Forceps
Ring stand and rings
Spatula, stainless steel
Test tube clamp
Test tube holders
Test tube rack
Tongs, crucible
Tripod
Wire gauze, plain and heat-proof center

Light

Blueprint paper
Cellophane, assorted colors
Color top
Flashlight
Lamp, gooseneck
Lenses, concave and convex
Mirror, concave and convex
Mirrors, plain
Prism, equilateral

Machines and Friction

Balance, platform, and weights
Balances, spring, assorted
Gyroscope
Meter sticks
Pulleys, single and double
Rope, clothesline and cord
Scale, bathroom
Wood boards, assorted lengths

Magnetism

Blueprint paper
Compasses, magnetic
Iron filings, fine
Lodestone
Magnets, bar
Magnets, horseshoe
Magnets, U-shaped
Magnets, cylindrical
Magnetic needle, mounted
Nails, large, assorted
Steel needles, knitting
Steel needles, sewing
Tacks, iron

Miscellaneous

Aluminum foil
Baby bottles, Pyrex
Bags, paper and plastic
Bottles, assorted
Boxes, cigar and wood
Cans, assorted
Cardboard
Cement, household
Clothespins, spring type
Clay, modeling
Coat hangers, thin wire
Pins
Pots and pans, aluminum and Pyrex
Potholders
Razor blades
Rubber bands, assorted
Screws, assorted
Sealing wax
Soda straws
Cotton, absorbent
Funnels, metal and plastic
Glue and paste
Hose, garden
Jars, glass, assorted
Marbles
Nails, assorted
Nuts and bolts
Paints and paint brushes
Paper clips
Ping-pong balls
Sponges, assorted
Steel wool
String, assorted
Thread, assorted
Utensils (forks, knives, spoons)
Wood, strips and boxes

Plants

Bouillon cubes
Bulbs, assorted
Gelatin
Germinating boxes
Lens paper, microscope
Microscope
Nutrient agar
Petri dishes
Plants, assorted
Seeds, assorted
Slides, microscope
Soil, fertile
Soil-testing kit
Sprinkling can
Terrarium
Trowel

Sound

Musical instruments, toy
Telephone receiver and transmitter
Tuning forks, set
Wire, music or fine steel

Static Electricity

Balloons
Cat fur
Polyethylene bags
Rubber rods, hard

Electroscope
Glass rods
Pith balls
Silk cloth
Thread
Wood cloth

Tools

Cork borer
Drill
File, flat
File, round
File, triangular
Hacksaw and blades
Hammer, claw
Hammer, geological
Jackknife
Knife (not folding)
Pliers, with cutters
Sandpaper
Saw
Scissors
Screw drivers
Soldering iron and solder
Tin snips
Vise
Wrench

SUPPLEMENT B
Science Supplies Obtainable from Community Sources*

This is only a partial list of places in the community that are possible sources of items for a science program in the elementary school. Other sources that should not be overlooked are local factories, the janitor of the school, and the junior and senior high school science teachers.

Dime Store or Department Store

Balloons
Balls
Candles
Compasses (magnetic)
Cotton (absorbent)
Flashlights
Food coloring
Glues and paste
Inks
Magnifying glasses
Marbles
Mechanical toys
Mirrors
Mousetraps
Paperbook matches
Scissors
Sponges
Thermometers

Drugstore

Adhesive tape
Alcohol (rubbing)
Bottles
Cigar boxes
Cold cream
Corks
Cotton
Dilute acids, 1-5%
Dilute hydrogen peroxide (1½%)
Forceps
Heat resistant baby bottles
Limewater
Medicine droppers
Pipe cleaners
Rubber stoppers
Sodium bicarbonate
Spatulas
Straws
Sulfur
Tincture of iodine

Electrical Appliance Shop

Bell wire
Burned-out fuses and light bulbs
Dry cells
Electric fans
Electric hot plates
Flashlights
Flashlight bulbs
Friction tape
Magnets (from old appliances)
Soldering iron

Fabric shop

Cardboard tubes
Cheesecloth
Flannel
Knitting needles
Leather
Needles
Netting
Silk thread
Spools
Scraps of material

Farm or Dairy

Birds' nest
Bottles
Clay
Containers
Gravel
Hay or straw
Humus

Insects
Leaves
Lodestone
Loam
Rocks
Sand
Seeds

Fire Deparment

Samples of material used to extinguish various types of fires

Water pumping equipment

Garden Supply Store

Bulbs (tulip, etc.)
Fertilizers
Flower pots
Garden hose
Garden twine
Growing plants
Labels

Lime
Seed catalogs
Seeds
Sprinkling cans
Spray guns
Trowels and other garden tools

Gas Station

Ball bearings
Cans
Copper tubing
Gears
Gear transmissions
Grease

Inner tubes
Jacks
Maps
Pulleys
Tools
Valves from tires
Wheels

Grocery Store

Ammonia
Baking soda
Borax
Candles
Cellophane
Clothespins
Cornstarch
Corrugated cardboard boxes
Fruits
Wax

Paper bags
Paraffin
Plastic wrapping
Salt
Sponges
Sugar
Tinfoil
Vegetables
Vinegar
Waxed paper

Hardware Store

Brace and bits
Cement
Chisels

Nuts and bolts
Paints and varnishes
Plaster of Paris

Clocks
Dry cell batteries
Electric push buttons, lamps, and sockets
Extension cords
Files
Flashlights
Fruit jars
Glass cutters
Glass funnels
Glass friction rods
Glass tubing
Hammers
Hard rubber rods
Insulated copper wire
Lamp chimneys
Metal and metal scraps
Nails
Wire

Pulleys
Sandpaper

Saws
Scales
Scrap lumber
Screening
Screwdrivers
Screws
Steel wool
Thermometers (indoor and outdoor)
3-6 volt toy electric motors
Tin snips
Turpentine
Wheelbarrow
Window glass
Yardsticks

Machine Shop

Ball bearings
Iron filings
Iron rods
Magnets

Nuts and bolts
Screws
Scrap metals
Wire

Medical and Dental Offices and Hospitals

Corks
Flasks
Funnels
Glass tubing
Hard lenses
Litmus paper
Microscopes

Models, such as teeth
Rubber sheeting
Rubber tubing
Rubber stoppers
Test tubes
Test tube holders
Thermometers
Tongue depressors

Music Shop

Broken string and drum heads
Musical instruments

Pitch pipes
Tuning forks

Pet Shop

Air pumps
Animal cages
Aquariums
Ant houses
Cages

Fish
Insects
Nets (butterfly, etc.)
Plastic tubing
Strainers
Terrariums

Restaurant, Diner, or Fast Food Outlet

Bones (chicken, etc.)
Bottles
Cans (coffee, 5 gallons)
Drums (ice cream)
Five gallon cans (oil)
Food coloring
Gallon jars (wide-mouthed, pickles, mayonnaise, etc.)

*Reproduced by permission. Source: Carin, Arthur A. and Sund, Robert B. *Teaching Science through Discovery*, 5th ed. Columbus, Ohio: Merrill Publishing Company, 1985.

SUPPLEMENT C
Garbage as a Source of Science Supplies

Appearing below is a list of items, many of which are occasionally to frequently found in household garbage. These items should be collected since they can all be utilized effectively when teaching elementary school science.

Glassware

- Pop bottles
- Catsup bottles
- Mayonnaise jars
- Pickle jars
- Wine bottles and corks

Containers

- Cups (plastic and paper)
- Egg cartons
- Gallon jugs (glass and plastic)
- Coffee cans
- Oleo tubs
- Small plastic containers (tomato or berry)
- Aluminum TV dinner trays
- Pie trays
- Plastic containers

Wooden Objects

- Spools (all sizes)
- Broomsticks
- Dowels
- Curtain shafts
- Clothes pins
- Scraps of wood

Miscellaneous

- Old golf balls, tennis balls, etc.
- Marbles
- Balloons
- Bottle tops
- Boxes (plastic, cigar, cardboard)
- Aluminum foil
- Cellophane wrap
- Insulation materials
- Parts from old toys, kits, etc.
- Linoleum squares
- Ceramic tiles
- Copper pipe and tubing
- Nuts and bolts
- Screws and nails
- Washers
- Mirrors
- Coat hangers
- Old 35 mm slides
- Film caps
- Tobacco cans
- Left-over paints
- Charcoal
- Milk cartons
- Paraffin
- Clay
- Soda straws
- Blotters
- BB shot
- Crayons
- Old pots, pans, trays, etc.
- Flower pots
- Sand, dirt, gravel, and sawdust
- Leather belts, pocketbooks, wallets
- Eye glass lenses
- Springs
- Wire (various kinds)
- Glass

Coffee cans
Cardboard (shirt inserts)
String
Fishing weights
Straight pins, tacks, thumbtacks
Old radios, TVs, etc.
Screening
Bottle tops or caps
Elastic materials
Pieces of material such as corduroy, silk, cotton, etc.
Cheesecloth
Thread
Flashlights
Eye droppers
Baby bottles
Wheels (skate, bicycle)
Old manila folders
Scissors
Old clocks
Stirring rods
Old silk stockings
Pill bottles
Paper tubes (toilet paper, towel, etc.)
Needles
Iron filings
Batteries

SUPPLEMENT D
Selected Commercial Scientific Equipment Suppliers

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
1-800-334-5551

Central Scientific Co.
11222 Melrose Ave.
Franklin Park, IL 60131
1-800-262-3626

Delta Education, Inc.
P. O. Box M
Nashua, NH 03061
1-800-258-1302

Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007
1-800-222-0224

Fisher Scientific Co.
Education Division
4901 W. LeMoyne St.
Chicago, IL 60651
1-800-621-4769

Sargent-Welch Scientific
7300 N. Linder Avenue
Skokie, IL 60077
1-800-633-6090

Science Kit, Inc.
777 E. Park Drive
Tonawanda, NY 14150
716/874-6020

Ward's Natural Science
Establishment, Inc.
P. O. Box 1712
Rochester, NY 14603
1-800-962-2660

SUPPLEMENT E
Resource Books for Elementary School Science Teaching

General Sources of Activities

Abruscato, J., & Hassard, J. *The whole cosmos catalog of science activities*. Glenview, IL: Scott Foresman, 1977. (A collection of science activities and games presented in an informal format.)

Blackwelder, S. *Science for all seasons: science experiments for young children*. Englewood Cliffs, NJ: Prentice-Hall, 1980. (activities that answer children's common questions)

Bybee, R., Peterson, R., Bowyer, J., & Butts, D. *Activities for teaching about science and society*. Columbus, OH: Merrill, 1984. (activities that relate to social needs and problems)

DeVito, A., & Krockover, G. H. *Creative sciencing: ideas and activities for teachers and children* (2nd ed.). Boston: Little, Brown, 1980. (about 160 activities designed to stimulate creativity)

Hone, E. B., Joseph, A., & Victor, E. *Sourcebook for elementary science*. New York: Harcourt, Brace, Jovanovich, 1971. (an extensive collection of science activities, with specific instructions)

Jacobson, W. J., & Bergman, A. *Science activities for children*. Englewood Cliffs, NJ: Prentice-Hall, 1983. (activities in eight subject areas for primary and intermediate levels)

Lorbeer, G., & Nelson, L. *Science activities for elementary children* (8th ed.). Dubuque, IA: Wm. C. Brown, 1984. (designed to provide teachers and students with a variety of demonstrations, class activities, etc. for science study)

Munson, H. R. *Science activities with simple things*. Belmont, CA: Pitman Learning, 1972. (fifty-three interesting activities with such common materials as rubber bands, paper clips, and milk cartons)

Neuman, D. B. *Experiences in science for young children*. Albany, NY: Delmar, 1978. (contains many basic open-ended activities for preschool and early primary levels)

Schmidt, V., & Rockcastle, V. *Teaching science with everyday things* (2nd ed.). New York: McGraw-Hill, 1982. (A well-conceived and illustrated book on how to teach science with common objects.)

Professional Texts

Abruscato, J. *Teaching children science*. Englewood Cliffs, NJ: Prentice-Hall, 1982.

Blough, G., & Schwartz, J. *Elementary school science and how to teach it*. New York: Holt, Rinehart, and Winston, 1984.

Carin, A. A., & Sund, R. B. *Teaching science through discovery* (5th ed.). Columbus, OH: Merrill, 1985.

Cain, S. E., & Evans, J. M. *Sciencing: an involvement approach to elementary science methods*. Columbus, OH: Merrill, 1984.

DeVito, A., & Krockover, G. H. *Creative sciencing: a practical approach*. Boston: Little, Brown, 1980.

Edwards, C. H., & Fisher, R. L. *Teaching elementary school science: a competency-based approach*. New York: Holt, Rinehart, and Winston, 1977.

Esler, W. K., & Esler, M. K. *Teaching elementary science* (4th ed.). Belmont, CA: Wadsworth, 1984.

Gabel, D. *Introductory science skills*. Prospect Heights, IL: Waveland Press, 1984.

Gega, P. C. *Science in elementary education*. New York: John Wiley and Sons, 1986.

Good, R. G. *How children learn science*. New York: Macmillan, 1977.

Henson, K. T., & Delmar, J. *Elementary science methods*. New York: McGraw-Hill, 1984.

Holt, B., & Holt, G. *Science with young children*. Washington, D.C.: National Association for the Education of Young Children, 1977.

Jacobson, W. J., & Bergman, A. B. *Science for children*. Englewood Cliffs, NJ: Prentice-Hall, 1980.

Kauchak, D., & Eggen P. *Exploring science in elementary schools*. Boston: Houghton-Mifflin Co., 1980.

Peterson, R., Bowyer, J., Butts, D., & Bybee, R. *Science and society: a source book for elementary and junior high school teachers*. Columbus, OH: Merrill, 1984.

Rowe, M. B. *Teaching science as continuous inquiry* (2nd ed.). New York: McGraw-Hill, 1978.

Trojcak, D. Science with children. New York: McGraw-Hill, 1979.

Victor, E. Science for the elementary school (5th ed.). New York: Macmillan, 1985.

Wolfinger, D. M. Teaching science in the elementary school. Boston: Little, Brown, 1984.

TOPIC 8: THE OUTDOORS AS AN EXTENSION OF THE CLASSROOM

J. William Dapper
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Learning experiences for elementary school children should extend beyond the classroom. Children talk about going outside to play at recess and coming back inside after recess to work. It is important to change their concept of the value of the outdoors as a place to learn.

Each year relevant science experiences for children should be conducted outdoors. Why shut them off from nature and treat the classroom as the only world where learning takes place? Many teachers shortchange their students by staying in the classroom and utilizing only traditional visual aids (charts and models). However, teachers should capitalize on students' curiosity and interest in living plants and animals as they are found in their natural habitats.

Field trips on the local school campus should be carefully planned so that time is not wasted; specific objectives related to learning experiences and evaluative objectives are to be considered as an integral part of each science activity. Experiences in the outdoors can be used to introduce new ideas and to motivate experimentation which may be conducted in the classroom and/or outdoors.

Sample activities are provided which hopefully will stimulate students to become more aware of the outdoor environment and which will require them to hypothesize, experiment, and gather data. Numerous sources of books, booklets, cards, and periodicals are provided for those interested in further outdoor investigations.

ACTIVITY 1: HOW PLANTS ARE AFFECTED BY THE ENVIRONMENT

In the world of nature, the eradication or "extinction" of a species has always gone on. This is true for the large organism (such as the dinosaur) as well as for the small (such as the insectlike animals called trilobites). Major changes in climate have been associated with the extinction of many species.

Around the globe, environments are changing constantly. Some of these changes, even today, are processes of nature. An example was rudely brought to light one spring day in May of 1980 when Mount St. Helens in Washington decided to come alive. Her eruptions that continued for months destroyed the long time "habitats" of the plants and animals around about the region. They have been and will continue to be replaced by other species which find the "environmental factors" more favorable.

Human activities, too, are making dramatic changes in the environment worldwide. Some, but not all of these changes, may be harmful to the plants and animals, although there may be no immediately visible indication of this. Examples of harmful human intervention can be seen in the acid rain which is caused by pollution and in man's encroachment into wilderness habitats which prevents animals from mating or building nests.

All living organisms have a "genetic code" or limiting factor which determines the environmental conditions which can be tolerated by that organism. In other words, to be able to live in a particular environment, the organism must have its basic needs met. Some plants such as the dandelion have wide ranges of tolerance as you can see each spring when they invade your lawn. Other plants such as the trillium have a limited tolerance. If a single environmental factor such as the amount and frequency of rainfall, humidity, wind, temperature range, sunlight or shade, or mineral content of the soil is lower than the amount the organism requires, it cannot survive. That's why when people move into an area the plants and animals native to the area frequently disappear as the environment changes.

This activity is designed to help participants discover how plants react to changes in their environment. They will transplant 2 different clumps of soil and vegetation, one into the other's environmental habitat.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Begin the activity by summarizing information in the introduction.
2. Organize participants in groups and give directions for the transplanting.
3. Engage participants in making the transplants.
4. Involve participants in discussing results.

MATERIALS LIST

For each group of four participants:

2 sheets of plastic (4' x 4')
2 cardboard boxes (about 1½ cu. ft. or more)
1 spade or shovel
1 tape measure or ruler
anti-shock liquid
water
1 bucket
2 numbered sticks or stakes
4 data sheets (1 per participant)

ADVANCE PREPARATION FOR THE INSTRUCTOR

Traverse the outdoor area to be used in the instructional process and choose microenvironments that are marked by different vegetation but with similar environmental factors (elevation, slope, amount of rainfall, temperature). Obtain spades or shovels for digging. Cut plastic into sheets 4' x 4'. Get permission in advance to dig in the study area and see that the area is not mowed.

TEACHING SEQUENCE

1. Introduce the activity by presenting a summary of the information in the introduction to the activity.
2. Organize the participants into groups of four. Supply them with the needed equipment and handout Direction For Transplanting (Teaching Aid 1) and Data Sheet (Teaching Aid 2). Review the handouts.
3. Escort the participants to the outdoor area previously selected. Introduce the participants to the microenvironments nearby that are marked by different vegetation, but with similar environmental factors (elevation, slope, amount of rainfall, temperature, etc.). Give them time to survey the area and choose their plots according to the outlined procedure.

When the transplants are in place, have the participants record the time of day, date, weather conditions, and locations (or stake numbers) of the transplants on their data sheet. Ask the participants to predict what will happen to the transplants over a period of time and record their predictions.

4. During the days that follow, have the participants make spot checks and record what they observe and whether the plants were able to survive in their new environment. Engage participants in discussing their observations and interpretations. Questions to encourage discussion are:

   - How did the plants compare in their adaptation to the change?
   - How did the survival rate compare in different types of soil?
   - What environmental factors might have affected your transplants?
   - What have you discovered about various environmental factors and plant growth?
   - Why do bananas not grow well in Mississippi?
   - Why do farmers not plant cotten in Iowa?

DIRECTIONS FOR TRANSPLANTING

After the transplant areas have been choosen, a plot about 20 cm x 20 cm should be measured off and marked with numbered stakes.* A bucket of water containing antishock plant liquid should be poured over the sample plot. Give the water a few minutes to sink in. Then with a shovel dig up the sample. Place it in a box lined with plastic. Wrap the plastic over it to prevent moisture from escaping. Then follow the same procedure at the second plot. Next, the first transplant should be inserted into the second plot, and the second transplant should be inserted into the first plot. When the transplants have been relocated, additional water with antishock liquid may be poured on.

---

*Trees and shrubs should not be included in the transplants.

DATA SHEET

Plot Stake Number ______

Date: ______________________________

Time of Day: ______________________________

Weather Conditions: ______________________________

Plants in Sample: ______________________________

DATE ______ OBSERVATIONS ______

____

____

____

____

This experiment showed that ______________

____

____

____

Plot Stake Number ______

Date: ______________________________

Time of Day: ______________________________

Weather Conditions: ______________________________

Plants in Sample: ______________________________

DATE ______ OBSERVATIONS ______

____

____

____

____

This experiment showed that ______________

____

____

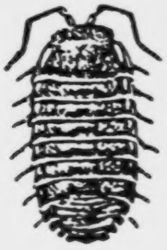
____

ACTIVITY 2: HABITAT SELECTION OF PILL BUGS (OR SOW BUGS)

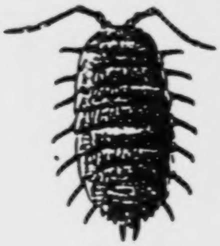
Pill bugs and sow bugs possess gills and are related to shrimp and crabs. Thus, they are crustaceans of the order Isopoda. They are commonly found in habitats such as under leaf litter, rocks or boards. Both of these isopods are quite similar in appearance; yet there are some obvious differences. Pill bugs have an arched body and can roll into a ball when disturbed. This ability helps them to conserve water loss as well as to provide protection from predators. Sow bugs, on the other hand, have more flattened bodies, and most are unable to roll up into balls. Like other crustaceans, these isopods have segmented bodies and legs, and hatch from eggs.

These isopods lose water in four basic ways: through their exoskeleton in general, from evaporation from respiratory membranes, in their feces, and during excretion of nitrogen. Their food selection is determined largely by their water needs and their dependence on a source of copper. They use nearly all of their behavioral options in dealing with water economy as it is a central problem in living on land.

They are a source of food for birds, certain spiders, amphibians, and centipedes. They, in turn, are an important part of soil ecology. They eat fleshy fruits, fungi, seedlings, dead and decaying matter, ant droppings, spiders' eggs, as well as their own feces.



Pill Bug



Sow Bug

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Introduce the activity.
2. Instruct participants in the preparation of the Petri dish habitats.
3. Involve participants in collecting isopods.
4. Give instructions for testing the habitats.
5. Discuss results.

MATERIALS LIST

For each group of 4 participants:

3 pairs of scissors
3 Petri dishes (complete units = covers and bottoms), 5½" in diameter or larger
2 sheets of black construction paper
1 sheet of white construction paper
1 paper towel
1 candle or paraffin block
1 wax melting pot
1 book of matches
1 timer with second hand or 1 large clock with a second hand
1 roll of cellophane tape
4 plastic sandwich bags
4 data sheets, each consisting of 2 different pages

ADVANCE PREPARATION FOR THE INSTRUCTOR

Traverse the area and choose the places nearby where pill bugs or sow bugs may be found - under logs, stones, branches, and leaf litter.

TEACHING SEQUENCE

1. Explain to the participants that in this activity they will collect pill bugs or sow bugs and explore the type of habitat preferred by them. Using information in the introduction to this activity, describe the difference between a pill bug and a sow bug.

2. Organize the participants into groups of four, and give each group 3 Petri dishes, 1 sheet of white construction paper, 2 sheets of black construction paper, 1 paper towel, 3 pairs of scissors, 1 candle, 1 wax melting pot, a book of matches, and 1 roll of cellophane tape. Have them prepare the dishes as shown in the illustrations on Directions For Preparation of Petri Dishes (Teaching Aid 1). Then they should label them (A, B, C) and set them aside for later use.

   After the Petri dishes are completed, ask the participants to predict which will be the number one choice of habitat, the number two choice, etc.

3. Give each participant a plastic specimen bag and inform them about collecting the isopods. Tell them that they will need to look under logs, stones, boards, leaves and in other similar places to find these isopods. Each team should collect about 10 of these bugs. They may use their hands, since the bugs will not bite. They should put them into their plastic specimen bags along with a few moist dead leaves and transport them safely back to the classroom where they will be tested in three different Petri dish habitats. Preferably,

all ten of the specimens should be one kind (either all pill bugs or all sow bugs) not a mixture.

Take the group outside to forage through the preselected area for either pill bugs or sow bugs. Then return to the classroom with the specimens.

4. In the classroom, instruct the participants to:

   - Put ten specimens into the Petri dish habitat A, 5 shaded and 5 exposed to the light. Time them for five minutes. At one minute intervals check to see how many are in the shaded and unshaded areas. Record the data on the Data Sheet (Teaching Aid 2).

   - Next, put the 10 specimens into the Petri dish habitat B, 5 on the dark substrate and 5 on the light substrate. Time for five minutes. At one minute intervals record how many are on each surface and record the data on the Data Sheet.

   - Finally, put the 10 specimens in the Petri dish habitat C, 5 on the moist side and 5 on the dry side. Time them for 5 minutes. At one minute intervals check to see how many are on each surface and record the results on the Data Sheet.

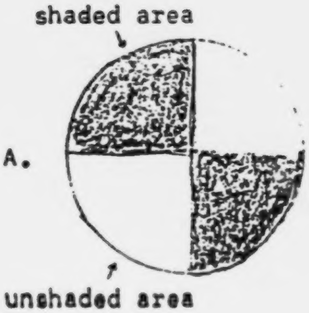
   - Total the numbers for each habitat and determine the percent in each mini-habitat. Graph the results on the Observation Graph.

5. From their observations, have the participants to draw conclusions as to which habitat or habitats the isopods considered most desirable, more desirable, least desirable. Information from the introduction could be shared if needed in interpreting results.

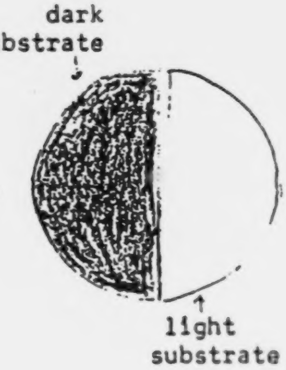
DIRECTIONS FOR PREPARATION OF PETRI DISHES

The first Petri dish will have covered and uncovered sections on the lid of the dish to allow for shaded and unshaded areas. The second Petri dish will have a dark background and a light background taped to the lower surface of the dish. The third and final Petri dish will have a candle wax median on the lower surface of the dish. A moistened paper towel will be placed on one side of the median, and the surface on the other side of the median will remain dry.

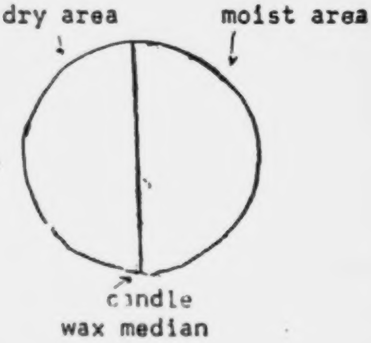
A.


shaded area
unshaded area

B.


dark substrate
light substrate

C.


dry area
moist area
candle wax median

DATA SHEET

Date:____

Specimens:_____________________________________

A.

Time	No. in Shaded Areas	No. in Unshaded Areas
1 min.		
2 mins.		
3 mins.		
4 mins.		
5 mins.		
Total		
Average		

B.

Time	No. on Dark Substrate	No. on Light Substrate
1 min.		
2 mins.		
3 mins.		
4 mins.		
5 mins.		
Total		
Average		

Teaching Aid 2

DATA SHEET

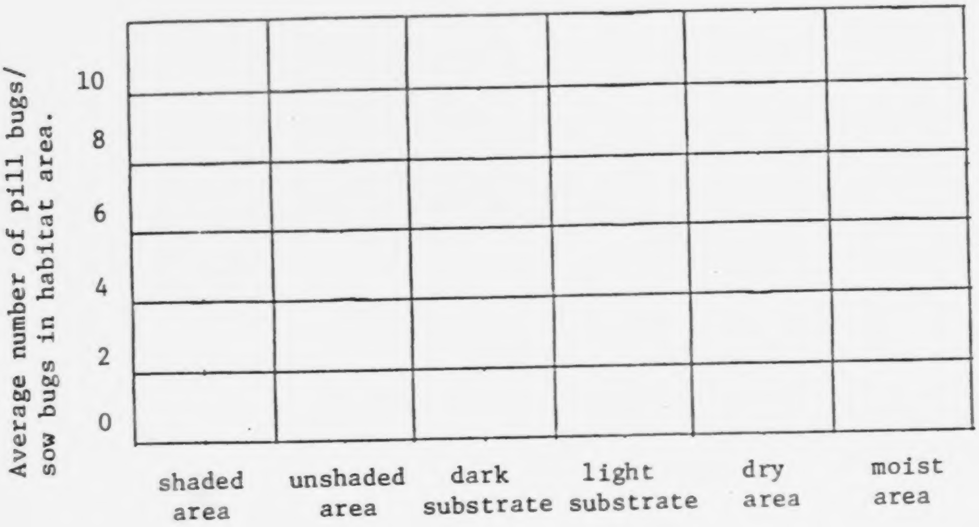
Date: ______________________________

Specimens: ________________________

C.

Time	No. in Dry Area	No. in Moist Area
1 min.		
2 mins.		
3 mins.		
4 mins.		
5 mins.		
Total		
Average		

BAR GRAPH OF OBSERVATIONS



Teaching Aid 2 (Cont)

ACTIVITY 3: A SURVEY OF SOIL ORGANISMS

Soil is composed of distinct layers called horizons. The upper horizon or A horizon is often referred to as top soil; it is composed of litter, humus, and a leached zone. The litter consists of dead plants and animlas or parts of them such as leaves, which represent the detritus component. Below the litter is humus; here the particulate matter has been reduced. The leached zone is light in color as a result of the movement of chemicals downwards with the flow of water.

The second major layer or B horizon is composed of mineral soil. The organic compounds have been converted by decomposers into inorganic matter. The third horizon or C horizon consists of unmodified parent material. It is composed of a mixture of decomposed rock and unchanged rock from which soil has not yet begun to form.

Soil moisture is influenced by the amount of rainfall, topography, texture of the soil, and the percent of organic matter present. Topography refers to surface features such as hilly versus flat terrain or north-facing versus south-facing slopes.

Texture is mainly due to the mineral matter of the soil. The range in diameter of the various soil particles is as follows: course sand, 2.0-0.2 mm; fine sand, 0.2-0.02 mm; silt, 0.02-0.002 mm; and clay, 0.002 mm and smaller. Soil that contains much clay holds water. Soil that is composed of approximately equal amounts of sand, silt, and clay is referred to as loam. Soils are named according to the relative amounts of components that are present (silt, loamy sand, clay loam, etc.). Organic matter usually constitutes only 2% to 5% of the soil by weight. Soil that is high in organic matter holds much water.

Soil consists of the weathered layer of the earth's crust with living organisms and products of their decay intermingled. This activity is designed to help participants discover the various animals that are associated with the soil. Berlese funnels will be constructed and utilized as the tool for getting animals out of the soil.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Introduce the activity.

2. Organize the participants in groups and give directions for preparing Berlese funnels.

3. Give directions for collecting soil samples.

4. Direct participants to areas for collecting soil samples.

5. Explain the procedure for collecting animals using the Berlese funnel.

6. Engage participants in graphing and interpreting data.

MATERIALS LIST

For each group of 4 participants:

1 trowel
1 plastic sandwich bag
1 plastic gallon milk jug
1 pair of scissors
1 ring stand
1 light bulb in portable extension socket or desk lamp
1 small baby food jar
1 piece of wire screen, 6 inches by 6 inches
1 piece of string, 32 inches long
1 animal survey sheet

For use by all groups:

1 quart isopropyl alcohol

ADVANCE PREPARATION

Traverse the area and select habitats that vary in soil moisture. Dry soil falls apart and sifts between the fingers; slightly moist soil appears moist but does not stick together when squeezed. In contrast moist soil sticks in a clump when squeezed. The presence of water is obvious when very moist soil is squeezed. Mark the preselected areas.

TEACHING SEQUENCE

1. Begin by sharing information in the introduction to the activity about soil that is pertinent to the activity. Explain that in this activity the participants will explore the variety and number of animals in various soil samples.

2. Organize the participants into groups of four. Give each group a plastic gallon milk jug, a pair of scissors, a ring stand, a light bulb in a portable extension socket, a baby food jar, and a piece of string. Have participants in each group prepare the Berlese funnels as shown in the Directions For Construction of a Berlese Funnel (Teaching Aid 1).

3. Give the following directions for taking soil samples outside:

> Each group should take a soil sample from a preselected area with soil moisture conditions different from that of the other groups. Samples should consist of soil taken down to a depth of seven inches. The surface area dug up should be about seven inches by seven inches.

4. Distribute to each group a plastic sandwich bag and trowel. Take the groups outside to the preselected areas for collecting.

5. Upon returning to the classroom, have each group follow these instructions:

   - Fill the bottom one inch of the baby food jars with isopropyl alcohol. This should not be done before collecting the soil samples because alcohol readily evaporates.

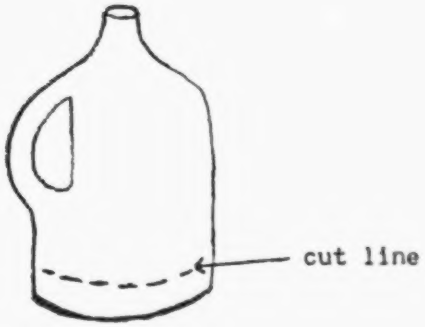
   - Place any litter on the wire screen and then cover it with the other components of the soil. By following this procedure, the alcohol is less likely to become contaminated with dirt.

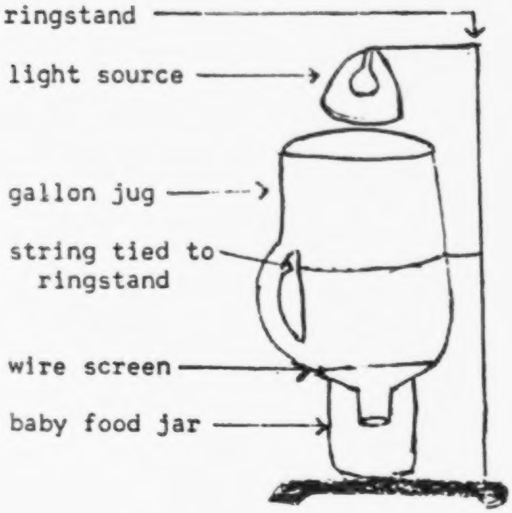
   - Turn on the light source for a 24-hour period. As the heat from the bulb dries the soil, the inhabitants of it will move downwards and will eventually fall into the jar of alcohol.

   - At the end of the time period, sort the preserved animals and count the number of each kind. Fill out the information on the Animal Survey Sheet (Teaching Aid 2); each group should use the same letter code for each specific kind of animal collected.

6. Using five different colors of chalk, have a member of each group make a composite line graph of the results on the chalkboard. Then determine if there is any correlation between the animals found and the amount of soil moisture present.

DIRECTIONS FOR CONSTRUCTION OF A BERLESE FUNNEL




ringstand
light source
gallon jug
string tied to ringstand
wire screen
baby food jar

Teaching Aid 1

ANIMAL SURVEY (8)

Animal Specimen Codes	Number Collected			
	Dry Soil	Slightly Moist Soil	Moist Soil	Very Moist Soil
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				
L				
M				
Total				

ACTIVITY 4: PLANT DISTRIBUTION ANALYSIS

A population is a group of individuals of any one kind of organism living in a given area. A community is more comprehensive; it consists of all of the populations (different kinds of organisms) living in a given area.

Ecologists call the total count of all individuals in a population a census. Sometimes it is possible to count every organism in a population. However, this is usually not done because it requires much time and money. Since it is seldom possible to count every individual organism in a population, scientists sample. When sampling, accurate information can only be obtained through random techniques. Therefore, the samples must be unbiased and adequate in size and number.

After samples are made and data tabulated, inferences are drawn about the community as a whole. Plot sampling brings to light the diversity, density, frequency, and coverage of various organisms within a plant community. The diversity of individuals of a community is what gives it stability. If one of the species is wiped out by a disaster of some sort, the area will not be devoid of living organisms even though its delicate balance is likely to have been upset.

Our study uses a simple census or habitat survey. It is a means of vegetative analysis that discloses the structure and composition of plant communities. For sampling plants, rectangular plots bear more accurate results than other shapes. Such a rectangle should be plotted with sides having a 1:2 ratio. Thus, we will base our plots on this formula.

This activity is designed to demonstrate that plant populations vary under different environmental conditions. Participants will obtain samples and compare plant populations that are present within and amongst three different study areas.

DIRECTIONS FOR WORKSHOP LEADER: SUMMARY

1. Begin the activity using information in the introduction.
2. Organize participants and materials for the collection procedure.
3. Explain the sampling procedure.
4. Direct participants in data analysis.
5. Promote and guide discussion about accumulated data.

MATERIALS LIST

For each group of 2 participants:

1 wire coat hanger
3 marker flags (3 different colors)
3 plastic sandwich bags (fold-top kind)
1 piece of string, 18 inches long
1 piece of cardborad (12" x 12") or clipboard
2 paperclips (if cardboard is used)
1 stapler with staples
1 trowel
1 pencil
1 data sheet
1 analysis sheet

ADVANCE PREPARATION

Traverse the area around the school, and select three different plots that are somewhat different in plant cover (great differences are not necessary). If possible, select one site in a sunny location, another site in a constantly shaded location, and a third site along a barrier such as a building or sidewalks. Each plot should be the same size and should cover an area of several square yards. The plots should be marked with flags and given letter designations (Plot A, Plot B, and Plot C).

TEACHING SEQUENCE

1. Explain to participants that this activity is designed to involve them in studying plant populations from different types of environments. They will obtain samples of plants and compare the plant populations that are present within and amongst three different study areas. Use information in the introduction to define the terms "population," "community," "sampling," and "population census."

2. Organize the participants in teams of two. Distribute to each team: one coat hanger, one Data Sheet (Teaching Aid 1), and 10 plastic sandwich bags. Show the participants how to attach the sandwich bags to their data sheet. The bags should be stapled carefully to the data sheet where indicated so that they are easy to open for inserting plant specimens; the bags will overlap. The data sheet should then be clipped to heavy cardboard (or a clipboard) to make them easier to use outside.

3. Describe the location of the three plots to be used as they study areas. Assign three to four teams to each plot. Explain the sampling procedure as follows:

   Once outside near the assigned plot a member of each team should close his eyes and toss the clothes hanger onto the plot so that the exact area of study will be randomly selected. After tossing the coat hanger onto the ground within the assigned plot, the different plants in the hanger area should be counted. A sample of each kind of plant found in the area of the coat hanger should be placed in a sandwich bag with different samples placed in different bags. If possible, the entire plant should be collected, including the roots. Each kind of plant found within the coat hanger area should be counted and the number recorded in the appropriate place on the data sheet.

If the grass plants are dense, then a length of string can be used to mark off the plants as they are counted. Each time ten plants of a kind have been counted, the string should be moved to encompass these plants (i.e. 10, then 20, then 30, etc.). It is not necessary to know the names of the plants.

4. Upon returning to class (while the samples are fresh), have all of the teams that woked in the same plot get together and compile their information on the Analysis Sheets (Teaching Aid 2). They should check to see how many different kinds of plants they found and which plants they have in common. They should total the number of each kind of plant and should then calculate the average number per coat hanger even if some plants were not present in all of the coat hanger areas studied.

5. Guide the participants in the interpretation of the data accumulated. Use the following questions to promote discussion and guide thinking:

   . What were the general characteristics of the three different plots investigated?

   . Which plants were found in all three of the plots? Did they survive equally well in each plot?

   . What environmental conditions tended to be best for each particular plant?

   . What assumptions can be made from the information gathered?

   . How could this information be of value to you in everyday life?

DATA SHEET

Location ________________ Partners ____________________

____

Plant Samples	Total Number of Each Kind of Plant
(attach bag here)	____
(attach bag here)	____
(attach bag here)	____
(attach bag here)	____
(attach bag here)	____

ANALYSIS SHEET

Location ____________________

Plant Samples	Team Totals				Plant Totals	Average Number
	Team 1	Team 2	Team 3	Team 4		

Teaching Aid 2

SOURCES FOR OUTDOOR EDUCATION

Bachert, Russel E., Jr., editor. *Hundreds of Ideas for Outdoor Education*. Danville, Illinois: The Interstate Printers and Publishers, Inc., 1979.

Bybee, Rodger; Peterson, Rita; Bowyer, Jane; and Butts, David. *Activities For Teaching About Science and Society: Activities for Elementary and Junior High School*. Columbus: Charles E. Merrill Publishing Company, 1984.

Crisp, Wynnlee. *Development and Use of the Outdoor Classroom*. Mutuchen, New Jersey: Scarecrow Press, Inc., 1975.

Ford, Phyllis M. *Principles and Practices of Outdoor-Environmental Education*. New York: John Wiley & Sons, Inc., 1981.

Garrison, Cecil. *Outdoor Education: Principles and Practices*. Springfield, Illinois: Charles C. Thomas, Publisher, 1966.

Gross, Phyllis P., and Railton, Ester P. *Teaching Science in an Outdoor Environment: Handbook for Students, Parents, Teachers, and Camp Leaders*. Berkeley: University of California Press 1972.

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Link, Michael. *Outdoor Education: A Manual for Teaching in Nature's Classroom*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1981.

Minnesota Environmental Sciences Foundation, Inc. The Environmental Units (24 titles in the Environmental Discovery Series). Washington, D.C.: The National Wildlife Federation. (National Wildlife Federation, Educational Servicing, 1412 16th Street, N.W., Washington, D.C. 20036.

Nelson, Leslie W., and Lorbeer, George C. *Science Activities for Elementary Children*. Dubuque, Iowa: William C. Brown Company, Publishers, 1984.

Rillo, Thomas J. *Outdoor Education: Beyond the Classroom Walls*. Bloomington, Indiana: Phi Delta Kappa, 1985.

Schmidt, Victor E., and Rockcastle, Verne N. *Teaching Science With Everyday Things*. New York: McGraw-Hill Book Company, 1968.

Sisson, Edith. *Nature With Children of All Ages: Adventures for Exploring, Learning, and Enjoying the World Around Us*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1982.

Smith, Julian, et al. *Outdoor Education*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972.

Staley, Frederick A. Outdoor Education for the Whole Child. Dubuque, Iowa: Kendall-Hunt, 1979.

The Science Curriculum Improvement Study. Teacher's Guide: Communities. Delta Education, P. O. Box M, Nashua, N.H. 03061-6012.

The Science Curriculum Improvement Study. Teachers' Guide Environments. Delta Educaton, P. O. Box M, Nashua, N.H. 03061-6012.

Trojcak, Doris A. Science With Children. New York: McGraw-Hill Book Company, 1979.

Unified Science and Mathematics for Elementary Schools. Nature Trails. Newton, Massachusetts: Education Development Center, Inc., 1974. (Available from ERIC*)

Wheatley, John H., and Coon, Herbert L. One Hundred Teaching Activities in Environmental Education. Columbus: The ERIC Center for Science, Mathematics, and Environmental Education, 1973.*

Wheatley, John H. and Coon, Herbert L. Teaching Activities in Environmental Education (3 volumes). Columbus: The ERIC Center for Science, Mathematics, and Environmental Education, 1975.*

*Address for ERIC:

ERIC Clearinghouse For Science, Mathematics, and Environmental Education
Room 310
1200 Chambers Road
Columbus, Ohio 43212-1792
Home: (614) 422-6717

Periodicals

Journal of Environmental Education. Quarterly. Heldref Publications, 400 Albermarle Street, N.W., Suite 500, Washington, D.C. 20016.

National Geographic World. Monthly. National Georgraphic Society, Department 00183, 17th and M Streets N.W., Washington, D.C. 20036.

Ranger Rick. Monthly. National Wildlife Federation, 1412 Sixteenth Street, N.W., Washington, D.C. 20036.

Science Activities. Quarterly. Heldref Publications, 400 Albemarle Street, N.W., Suite 500, Washington, D.C. 20016.

Science and Children. 8 issues/year. National Science Teachers Association, 1742 Connecticut Avenue, N.W., Washington, D.C. 20009.

Your Big Backyard. Monthly. National Wildlife Federation, 1412 Sixteenth Street, N.W., Washington, D.C. 20036.

TOPIC 9: AN INTERDISCIPLINARY APPROACH TO TEACHING SCIENCE

Nancy Sissell Major
South Panola Consolidated School

Learning comes naturally to children. They are born with an innate curiosity, eager to explore the world about them first-hand. Sadly enough, in recent years schools across the country have stifled this natural inclination, largely as a result of the "Back to Basics" movement. Science education in elementary schools has suffered. Today science is more often than not offered as the lagniappe of the curriculum--a little something extra offered at the end of the day, if time permits. Pressed for time, short on materials, and with test scores looming ahead, teachers make a sincere effort, but too often there is barely time even for the lesson in the adopted text. Science comes to mean, so far as the child is concerned, a page or chapter in a textbook and nothing more.

What can be done to change the child's perception of the subject? How can we make him conscious of the science all around him? What can be done to give teachers adequate time for teaching science?

Using an interdisciplinary approach--teaching science while teaching another subject--is highly practical for four reasons. First, it is efficient use of time. Economy of teaching time is achieved when a teacher multiplies her hours and her effort by combining subjects. A teacher may not have time for a separate science lesson each day, but when integrated with "prime time basics," such as reading and math, daily classroom contact with science is ensured.

Secondly, an interdisciplinary approach reinforces learning for students. Many concepts, process skills, and problems found in science are also central to other disciplines. Each experience, each bit of information the child processes, will reinforce related learnings from the other subjects.

Thirdly, an interdisciplinary approach is motivating for students. By presenting a skill in a variety of contexts, teachers are more likely to appeal to the multiple learning styles present in a particular class. The child's natural curiosity is stimulated, even exploited, by approaching a concept through non-obvious avenues. The child is more likely to internalize the concept of science as happening all around, all the time, everywhere from nature to high tech, that science is an important part of his everyday life.

Finally, science lends itself quite naturally to integration with other disciplines--reading, language arts, mathematics, social studies, fine arts. In doing so, our schools can more accurately reflect the "real-life" relationships between science and other subjects.

Interdisciplinary teaching of science has been proven successful. Authorities cite the need for repeated contact with a concept for mastery,[1] which could be accomplished by integrating subjects. The heightened motivation that science offers other subjects has been recognized,[2] and the importance of a coherent curriculum as a much-needed counter-balance to the fragmentation that T.V. presents to our children has been clearly stated.[3] Research shows that, on tests of basic skills in reading readiness, reading skills in the intermediate grades, language arts, oral and written communication, language development of children with special needs, and in mathematics and social studies, there was an increase in scores when those subjects were integrated with science.[4]

During this session participants will practice two approaches to integrating science with other subjects. They will design science lessons based on stories from basal readers, bringing science content and process skills into the reading lesson. Then, they will take traditional science materials and relate these to other subject areas. The results of the session will be materials for each teacher to use in her own classroom.

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[1] Hunter, Madeline, Teach for Transfer(El Segunda, California: TIP Publication, 1971), p. 55.

[2] Maine, Edna, "Interrelating Science With Other Subjects," Science and Children, February, 1981, pp. 26-27.

[3] Postman, Neil, Teaching As a Conserving Activity (New York: Delacourt Press, 1979), p. 130.

[4] Holdzkom, David and Lutz, Pamela B., Ed., Research Within Reach: Science Education (Charleston, West Virginia: Research and Development Interpretation Service, Appalachia Educational Laboratory, Inc., 1985), pp. 79-107.

ACTIVITY 1: TEACHING SCIENCE FROM A BASAL READER

This activity is designed to engage participants in designing science lessons from various stories in basal readers. Science content and process skills will be suggested by the stories.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Explain the rationale for interdisciplinary teaching of science as discussed in the introduction to the topic.
2. Show examples of an interdisciplinary lesson using a webbing sheet.
3. Lead the group in working an example together.
4. Guide small groups as they work on lesson outlines.
5. Encourage sharing among groups.
6. Provide a summary/closure for the workshop.

MATERIALS LIST

Participants will work in groups of 3 or 4, grouped by the grades they teach. Each group will need the following:

Copies of basal readers for their grade level from several different publishers
3-4 webbing sheets per participant
pencils or pens for each participant
chalkboard or overhead projector for leader
Copies of the handout, Process Skills--AAAS Listing (Topic 3/ Activity 1, Teaching Aid 2)
Teaching Aids 1-3 (Webbing Examples)

ADVANCE PREPARATION

The various basal readers should be grouped by grade levels so that each group of 3 or 4 participants will have several books with which to work. By securing as many different series as possible, each teacher will have access to the series adopted by her school, as well as other books which could be used for supplementary material.

TEACHING SEQUENCE

1. Pose the question, "Do you, as a teacher, have adequate time and materials to teach as you would like to each day? Have you ever run out of time before accomplishing your objective for the day's lesson? Do you ever feel threatened by tests, time, etc.?"

   Use information provided in the introduction to introduce participants to the practicality of interdisciplinary teaching. Review the processes of science (Topic 3/Activity 1, Teaching Aid 2, Process Skills--AAAS Listing) and the fact that these processes can be practiced (especially the Basic Processes) in many different contexts.

   State the purpose of the first activity: The purpose of the session is to learn to teach science through a time-efficient strategy that is extremely motivating and reinforcing to students.

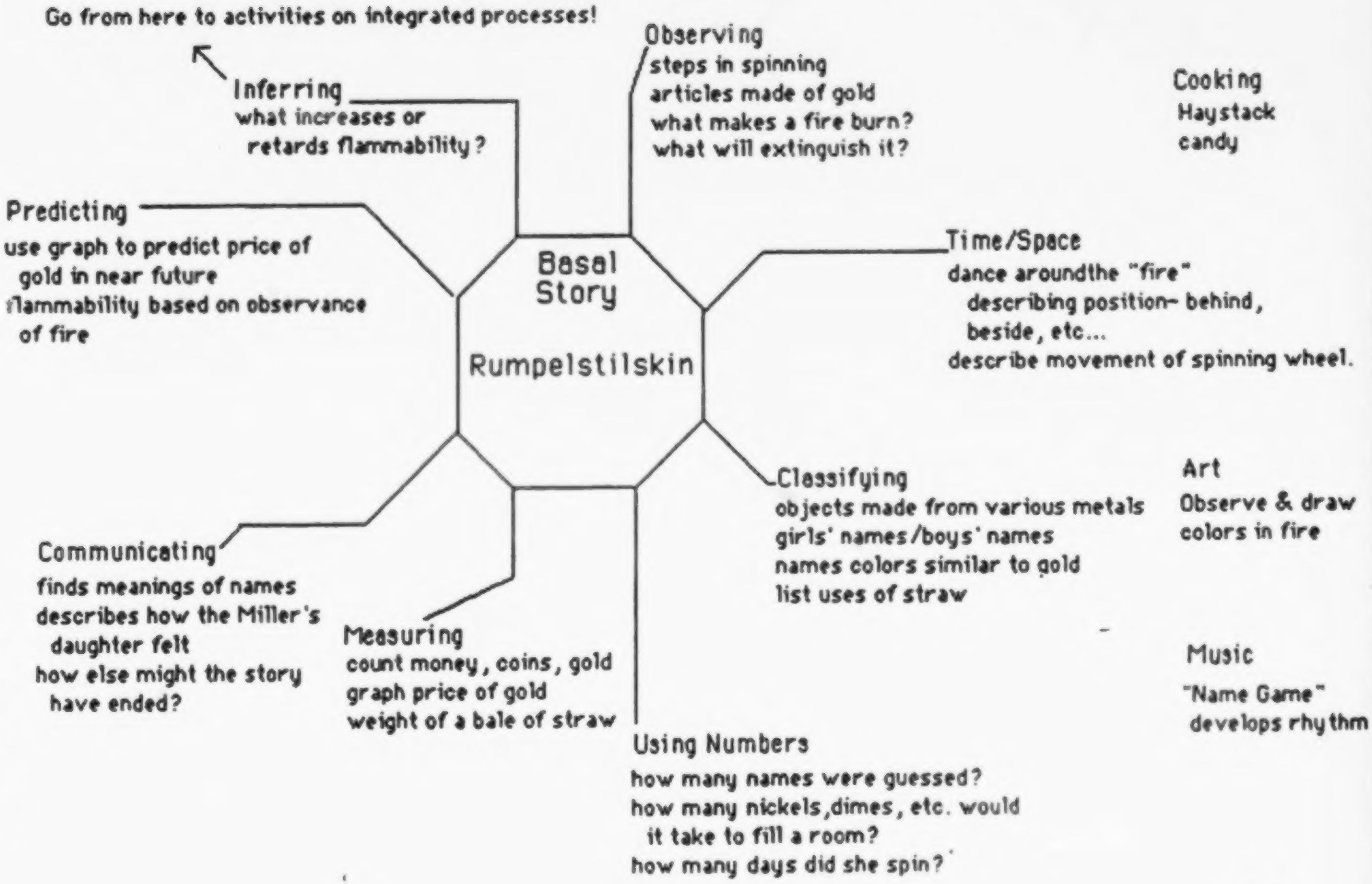
2. Still working in a large group, recall the familiar story of Rumpelstilskin (Teaching Aid 1). Give synopsis of story, with illustrations. In this initial example the leader will demonstrate the concept of webbing. Refer to Process Skills (AAAS Listing) and identify science processes that might be practiced during the reading of this story. Begin webbing the story. Look for specific science topics within the story. Use Web of Rumpelstilskin (Teaching Aid 1) to illustrate as needed.

3. Work through a second example, still in a large group, letting participants choose a story and supply information for webbing. Does the story lend itself to integration with other subjects, as well as with science? A sample web for the book Charlotte's Web and the holiday, Columbus Day, may be used to illustrate (Teaching Aids 2 and 3).

4. Divide participants into groups of 3-4 by grade. Assist each group as it develops its plan. If time permits, look for ways to incorporate other subjects or begin work with another story.

5. When group plans are completed, ask for a spokesman to share the group's favorite plan. During the sharing time, or afterwards, participants should be able to compile a list of specific reasons why this approach would be so appealing to children, enhancing both the science and reading lessons.

6. Close the activity by leading the participants in reviewing the most obvious reasons for using an interdisciplinary approach to teaching science and outlining the method for accomplishing the strategy.



Go from here to activities on integrated processes!

Inferring
what increases or
retards flammability?

Observing
steps in spinning
articles made of gold
what makes a fire burn?
what will extinguish it?

Cooking
Haystack
candy

Predicting
use graph to predict price of
gold in near future
flammability based on observance
of fire

Basal
Story

Rumpelstilskin

Time/Space
dance aroundthe "fire"
describing position– behind,
beside, etc...
describe movement of spinning wheel.

Classifying
objects made from various metals
girls' names/boys' names
names colors similar to gold
list uses of straw

Art
Observe & draw
colors in fire

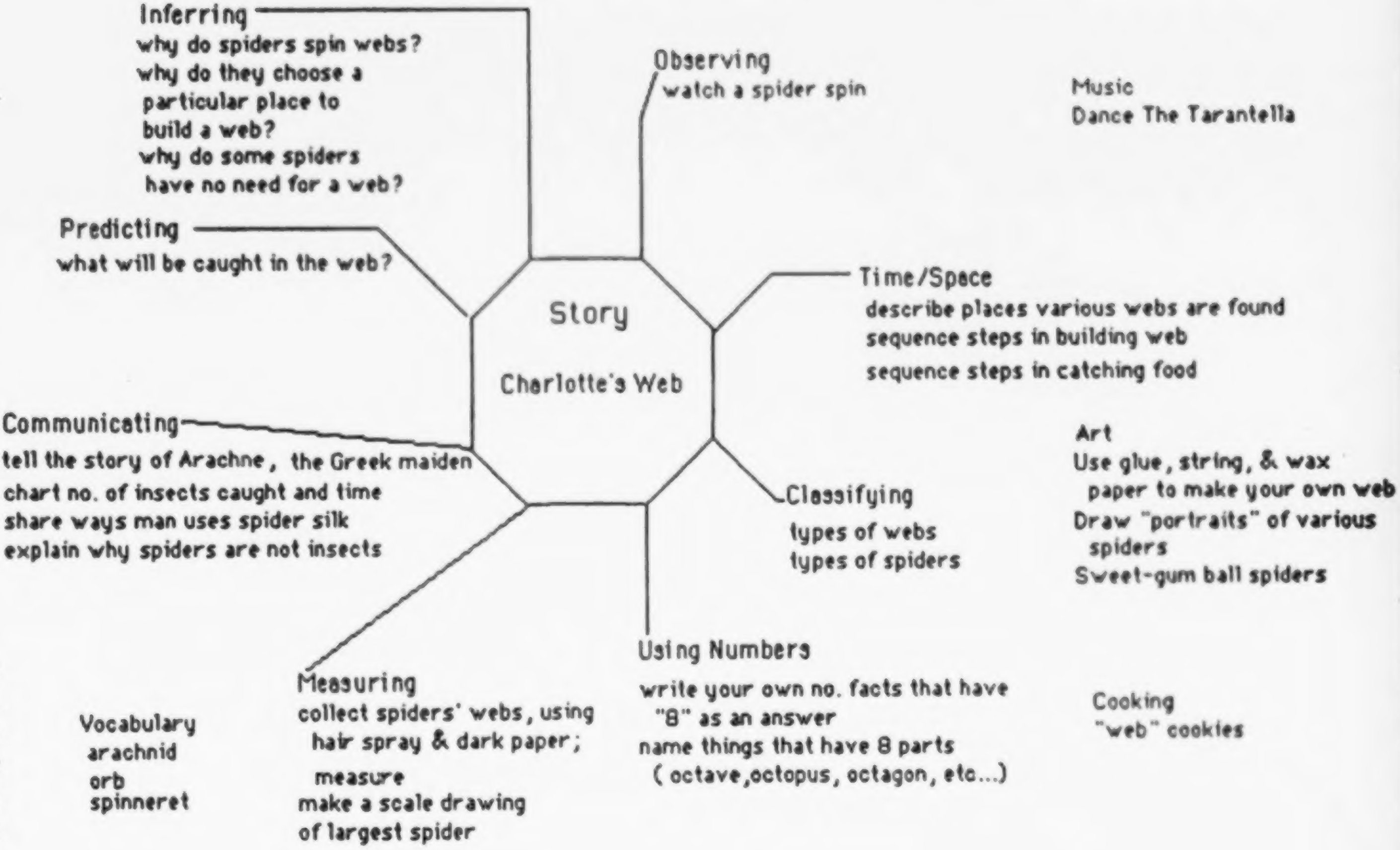
Communicating
finds meanings of names
describes how the Miller's
daughter felt
how else might the story
have ended?

Measuring
count money, coins, gold
graph price of gold
weight of a bale of straw

Music
"Name Game"
develops rhythm

Using Numbers
how many names were guessed?
how many nickels, dimes, etc. would
it take to fill a room?
how many days did she spin?

Topic 9 / Activity 1
Teaching Aid 1
(Transparency)



Story

Charlotte's Web

Inferring
why do spiders spin webs?
why do they choose a particular place to build a web?
why do some spiders have no need for a web?

Observing
watch a spider spin

Music
Dance The Tarantella

Predicting
what will be caught in the web?

Time/Space
describe places various webs are found
sequence steps in building web
sequence steps in catching food

Communicating
tell the story of Arachne, the Greek maiden
chart no. of insects caught and time
share ways man uses spider silk
explain why spiders are not insects

Classifying
types of webs
types of spiders

Art
Use glue, string, & wax paper to make your own web
Draw "portraits" of various spiders
Sweet-gum ball spiders

Vocabulary
arachnid
orb
spinneret

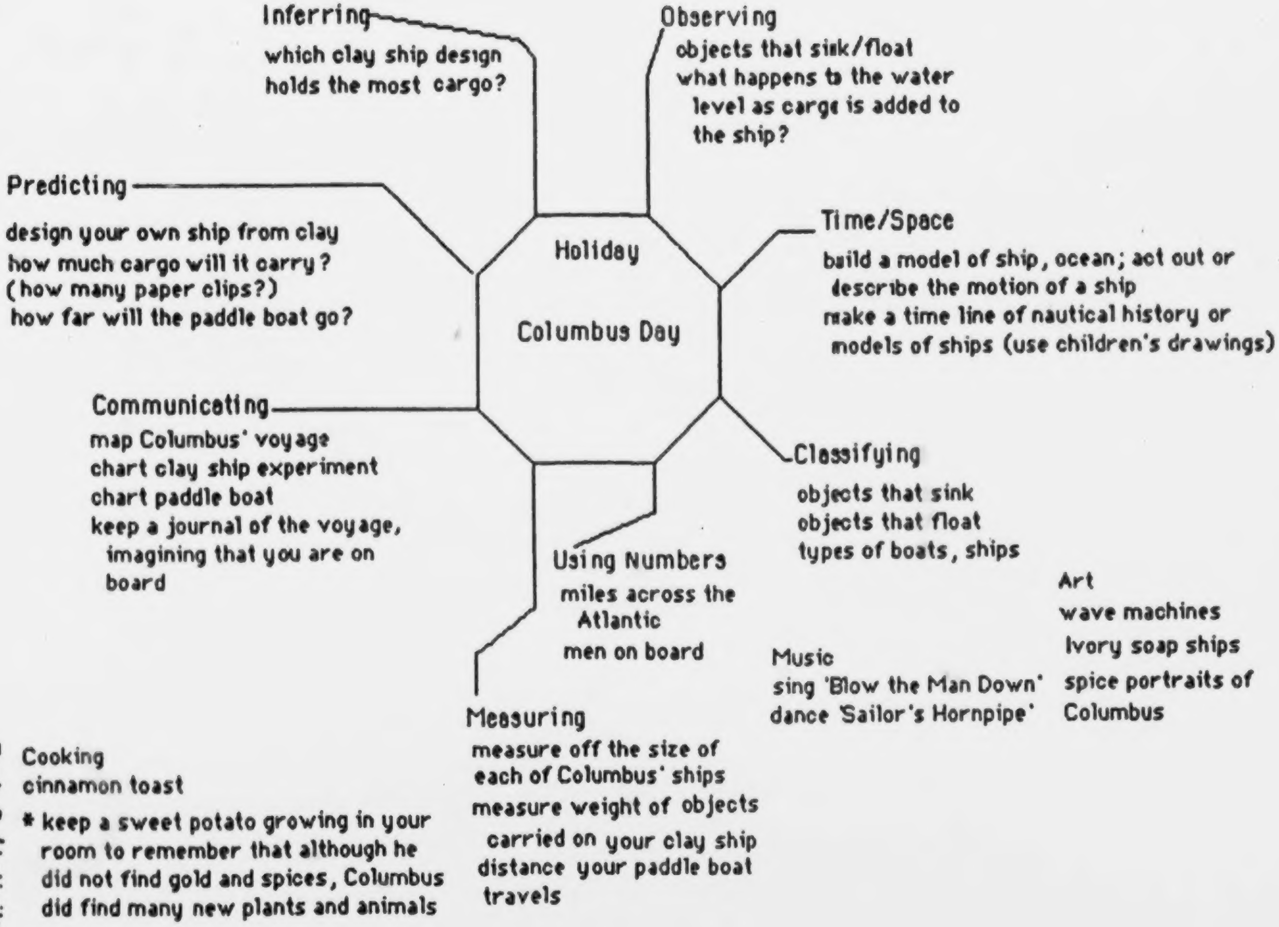
Measuring
collect spiders' webs, using hair spray & dark paper; measure
make a scale drawing of largest spider

Using Numbers
write your own no. facts that have "8" as an answer
name things that have 8 parts (octave, octopus, octagon, etc...)

Cooking
"web" cookies

Topic 9 / Activity 1
Teaching Aid 2
(Transparency)

Topic 9 / Activity 1
Teaching Aid 3
(Transparency)



Holiday

Columbus Day

Inferring
which clay ship design
holds the most cargo?

Observing
objects that sink/float
what happens to the water level as cargo is added to the ship?

Predicting
design your own ship from clay
how much cargo will it carry?
(how many paper clips?)
how far will the paddle boat go?

Time/Space
build a model of ship, ocean; act out or describe the motion of a ship
make a time line of nautical history or models of ships (use children's drawings)

Communicating
map Columbus' voyage
chart clay ship experiment
chart paddle boat
keep a journal of the voyage, imagining that you are on board

Classifying
objects that sink
objects that float
types of boats, ships

Using Numbers
miles across the Atlantic
men on board

Measuring
measure off the size of each of Columbus' ships
measure weight of objects carried on your clay ship
distance your paddle boat travels

Music
sing 'Blow the Man Down'
dance 'Sailor's Hornpipe'

Art
wave machines
Ivory soap ships
spice portraits of Columbus

Cooking
cinnamon toast
* keep a sweet potato growing in your room to remember that although he did not find gold and spices, Columbus did find many new plants and animals

ACTIVITY 2: MAKING YOUR SCIENCE LESSON COME TO LIFE

This activity is designed to engage participants in relating topics included in the science text to other subjects. Science content and process skills will be deliberately and consciously fused with other subject areas, current events, and daily life situations. Emphasis will be on connecting information in the science text with reinforcing material from other fields.

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

The workshop leader will:

1. Explain the procedure for webbing with the science topic as the core.
2. Lead the group in working an example.
3. Guide small groups as they work on plans.
4. Encourage sharing of results.
5. Summarize and close the session.

MATERIALS LIST

Participants will work in groups of 3 or 4, grouped by the grades they teach. Each group will need the following:

copies of science texts for their grade level from several publishing companies
3-4 webbing sheets for each participant
pencils or pens for each participant
recent newspapers, news magazines
various texts for each grade level from other subject areas
Teaching Aids 1-3
The workshop leader will need a chalkboard or overhead projector.

ADVANCE PREPARATION

Books and materials should be arranged by grade level, with current news available for each group. As in Activity 1, it is important for each teacher to have access to texts she would normally work with in her school, as well as new texts that she could use in the future as supplementary materials.

TEACHING SEQUENCE

1. If you teach in a school or a grade that is departmentalized, you may not teach reading. In upper elementary grades, a specific period is usually designated for science. Could you use the webbing strategy to connect science concepts to other subjects areas? If you can help students to realize the relationships between subjects, both subjects will become more meaningful.

   The purpose of Activity 2 is to practice webbing from a science concept to other subjects, current events, and real life situations.

2. Working in a large group, choose a familiar science topic and demonstrate how it could be related/reinforced through art, music, math, writing, reading, social studies, etc. activities. Look for current news topics that could be included. (These current events might also serve as the core of a webbing exercise.) The prepared webs for the science topics are Sound (Teaching Aid 1), Birds (Teaching Aid 2), and Water (Teaching Aid 3). Since the group should be familiar with the webbing procedure by now, one example should be sufficient; however, the leader may want to work through a second example.

3. Divide participants into groups of 3-4. Instruct each group to select a topic and develop a plan. Assist groups as needed.

4. Share results, encouraging participants to verbally list reasons why students would be motivated by this type of teaching.

5. Close the activity by leading participants in summarizing the reasons for using an interdisciplinary approach and outlining the method for accomplishing the strategy.

SUGGESTED READING

DeBruin, Jerry. Creative, Hands-On Science Experiences. Carthage, Illinois: Good Apple, Inc., 1980.

Hamilton, Dorothy. "Using Fine Art to Teach Science." Science and Children, September, 1981, pp. 7-10.

Holdzkon, David and Lutz, Pamela B., Ed. Research Within Reach: Science Education. Charleston, West Virginia: Research and Development Interpretation Service, Appalachia Educational Laboratory, Inc., 1985.

Hunter, Madeline. Motivation. El Segunda, California: TIP Publications, 1971.

Hunter, Madeline. Retention. El Segunda, California: TIP Publications, 1971.

Hunter, Madeline. Teach for Transfer. El Segunda, California: TIP Publications, 1971.

Lewis, Melanie. "Observing the Environment Through Art." Science and Children, September, 1981, pp. 11-12.

Maine, Edna. "Interrelating Science with Other Subjects." Science and Children, February, 1981, pp. 26-27.

Mechling, Kenneth and Oliver, Donna. Science Teaches Basic Skills, Handbook I. Washington, D.C.: National Science Teachers Assoc., 1981.

Postman, Neil. Teaching As a Conserving Activity. New York: Delacourt Press, 1979.

Science topic:
SOUND

Language Arts
onamatapoeia -sound words
write "I Couldn't Believe My Ears"
sign language

Reading
Alexander Graham Bell, Louis Braille
Chuck Yeager, Laura Bridgeman,
Thomas Edison
"I Have a Sister, My Sister is Deaf"
'Love is Never Silent' (movie)
communications in dolphins
biographies of composers

Math
measure decibels of sound
musical notes - fractions
speed of sound
cost of concert tickets

Cooking
collect recipes for
noisy foods, quiet foods
"vibration salad"
(jello)

Music
musical scale with bottles
musical instruments/ families
write and perform your own musical production
Leontyne Price-MS Musicians
rhythm games
what do ears have to do with dancing, gymnastics, etc...?

Vocabulary
echo, pitch, sonic,
decibel, amplitude,
acoustic, vibrate,
"audio words",
auditory

Social Studies
noise pollution
make a plan to improve acoustics in your room
careers/interviews

Science
Process Skills
Observing -length of string and pitch of sound
Time/Space - where is sound loudest?
Classifying - pleasant/ unpleasant sounds
Using numbers - decibels
Measuring -length of strings on instruments
Communicating - results of various experiments
Predicting -pitch of sound based on length of string or tube
Inferring -what causes sound; what affects quality of sound

Art
listen to various types of music and paint picture to match each type
take a close look at a friend's ears-make a sketch
sound wave designs

Topic 9 / Activity 2
Teaching Aid 1
(Transparency)

Topic 9 / Activity 2
Teaching Aid 2
(Transparency)

Science topic:

BIRDS

Language Arts

collect bird-related sayings:
"eat like a bird"
"head in the sand"
adjectives to describe various birds
list things that fly

Story starters:
"I'd build my nest..."
"The bird most like me ..."
Keep Bird Watcher's Book

Reading

find stories about largest bird, smallest bird, extinct birds, imaginary birds, birds that do not fly, state birds, national bird, poetry

Math

observe & record birds seen for 1 day period
graph
children can write their own story problems
compare weights of birds
study flight paths, migratory distances
measure wing span

Cooking

egg dishes

Vocabulary

ornithology, migrate, molt, flock, prey, quill, talon, down

Music

listen to recordings of bird calls
use duck, goose, turkey call

Social Studies

endangered birds
creating an inviting environment
careers
how pollution threatens birds
flocks cause problems in some communities (news)

Science

Process Skills

Observing - kinds of birds
Time/Space - describe movements
Classifying - by size, beak (food), habitat, flying/nonflying, etc...
Using numbers - keep observation count
Measuring - distance flown
Communicating - graph
Predicting - food eaten by beak, etc...
Inferring - cause for extinction of some species

Art

eggshell mosaic
feather painting
build a birdhouse
color names from birds (flamingo, robin)
writing with a quill

Topic 9 / Activity 2
Teaching Aid 3
(Transparency)

Science topic:
WATER

Language Arts
poem "Rain"
interview folks in your community to learn about signs of rain

Reading
Old Man and the Sea
Witch of Blackbird Pond
Mississippi River stories - Mark Twain
"Why the Sea is Salty" (folk tale)

Cooking
homemade ice cream
why is salt added?
trail mix with dried fruit
make your own raisins

Math
temperature measurement
collect a variety of thermometers
record the amount of water you use or consume in one day

Vocabulary
evaporation, condensation, solvent, dissolve, humidity, solution, precipitation,
"aqua" words,
"hydro" words

Music
compile a list of songs that include "water" or "rain" in their titles

Art
water gun painting
water color
water cycle mural
examine a drop of water under the microscope, sketch what you see

Science
Process Skills
Observing - evaporation; chart amt. of water each day
Time/Space - water cycle; rain distribution
Classifying - solids, liquids, gases; fresh/salt water
Using numbers - record precipitation and humidity for a month
Measuring - boiling point, freezing point, weight of fruit before/after drying
Communicating - charts from various experiments
Predicting - on all experiments have students write prediction
Inferring - the need of living things for water based on experiments with plants

Social Studies
locate nearby bodies of water
careers, water pollution
average rainfall for your area
investigate history of the umbrella
man's use of water for:
electricity, irrigation,
drinking, cleaning

TOPIC 10: CLASSROOM MANAGEMENT AND SAFETY IN ELEMENTARY SCHOOL SCIENCE

Rebecca Rainey
Hattiesburg Public Schools

The death blow to the use of hands-on experiences to teach science is most often due to classroom management problems. The noise, the movement of children about the room, the safety hazards, the children's excitement--all contribute to an uneasy feeling that things are getting out of control. Many teachers find it impossible to cope with the strain and resort to their old "teaching as telling" method after a few attempts.

This topic presents practical classroom management and safety suggestions. Careful planning related to classroom arrangement, group organization, rules of behavior, materials acquisition, and clean-up can result in a pleasant successful experience with hands-on science.

ACTIVITY 1: CLASSROOM MANAGEMENT TECHNIQUES

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Involve the participants in discussing aspects of classroom management, using suggestions provided in the teaching sequence.

2. Encourage participants to share from their experiences in handling hands-on activities.

ADVANCE PREPARATION

Review the suggestion for leading the discussion found in the teaching sequence.

TEACHING SEQUENCE

1. Involve the participants in discussing the following aspects of classroom management:

    a. classroom arrangement
    b. size and organization of groups
    c. preparation and handling of materials
    d. ground rules for student behavior
    e. use of rewards
    f. merits of overplanning

   The following suggestions were written to provide direction to you as the workshop leader in planning the discussion.

INTRODUCTION

You want to involve your class in hands-on science activities, but OH .. the noise, chaos, and what a headache for you! How can you provide meaningful classroom experiences without losing your sanity?

Both you and your students can enjoy hands-on activities. Classroom management may mean the difference between success and total disaster. Here are some suggestions for solving some of those classroom management problems:

CLASSROOM ARRANGEMENT

The arrangement of your classroom may affect hands-on activities. Basic classroom seating arrangements may prove adequate when students are working independently, or when demonstrations are provided for a large group.

Very few classrooms contain an adequate number of tables for students to use when in small groups. Using tables makes it easy for you to organize students and materials. If desks are used, they may be arranged in a huddle or circle facing inward. Elementary students may even sit in groups on the floor.

SIZE AND ORGANIZATION OF GROUPS

It may be best to limit groups to 4-5 students per group (depending on the activity). This encourages a larger number of students to interact within each group. When groups are chosen by the teacher, there is often a decrease in the number of problems that may occur during the activity. Each member of the group should be assigned a specific task, such as, (1) collecting the materials needed, (2) recording data, and (3) cleaning the work area, etc. Plan groups ahead of time to save confusion and to keep from wasting time.

PREPARATION AND HANDLING OF MATERIALS

Each group should have all the materials needed to complete the task. It often helps the activity flow more smoothly if the teacher has obtained all the materials needed ahead of time. These materials may be divided and organized in bags, boxes, on trays, etc. so that they may be easily distributed. A list of the materials to be found on each tray or in each box should be listed on the board so that students can check to be sure that they have all of the necessary items, both at the beginning and end of the activity. One member from each group may be chosen to obtain materials from a central location in the room. The same person (or another if you choose) would be responsible for returning the materials at the end of the class time. This helps to cut down on the movement of students within the room.

GROUND RULES FOR STUDENT BEHAVIOR

It always helps to set the ground rules before beginning an activity. Explain what the students will be doing and how you expect it to be done. A list of the rules should be posted in the room. If practiced consistently, students will learn to control their groups with only occasional reinforcement from the teacher. Some suggestions for ground rules are as follows:

(1) Keep talking limited to members of your group. (Children can be taught to speak softly during classes.) No visiting allowed among groups.

(2) Students are to remain seated with their groups during the activity unless required by the lesson or given permission by the teacher.

(3) If a group needs help from the teacher, the group leader should raise his/her hand and wait until the teacher comes to the group.

(4) Groups are responsible for cleaning their area and returning all materials to their proper places.

(5) Require reports (oral or written) from all groups before the class period is over. (This will help to insure that all groups remain on task.)

Group leaders could be chosen that would be responsible for directing the group during the activity. Often a low level student or one known for his "mischief" will "shine" if given the responsibility of leadership.

USE OF REWARDS

The possibility of earning a reward may be enough to insure a smooth-running class. It is amazing how much effort students will put into their work when a reward hangs in the balance. Just name your price! Possible rewards include:

(1) free time
(2) stickers
(3) game time
(4) computer time
(5) extra points, and many more!

Also, play tokens that can be accumulated and cashed-in for special rewards may be used effectively.

OVERPLANNING

There will be fewer discipline problems if the class time is used fully. It is best to have something planned as a follow-up activity should students finish early. This keeps them from disturbing other groups that are still working and reinforces what has been taught.

INSTRUCTIONAL LEADER

No matter what the activity, the teacher is the instructional leader. The teacher should motivate the class to work productively prior to the hands-on activity. Monitoring the class during the activity will keep you informed of each group's progress. The students should work independently, while being guided and observed by the teacher. Do not just turn the students loose to work; guide them through it. Finally, the teacher should involve the students in summarizing the activity and reviewing the objectives of the lesson.

2. Allow time for participants to share from their experiences in handling hands-on activities--the successful, as well as unsuccessful, attempts. Encourage them to analyze reasons for success or failure. Be sure to close the discussion on a positive basis for hands-on activities.

ACTIVITY 2: SAFETY IN THE ELEMENTARY SCIENCE CLASSROOM

DIRECTIONS FOR THE WORKSHOP LEADER: SUMMARY

1. Introduce the activity using Teaching Aid 1.
2. Review the NSTA guide, "Safety In The Elementary Science Classroom."
3. Encourage participants to share their concerns about maintaining a safe environment.

MATERIALS LIST

One copy of the NSTA publication, "Safety In The Elementary Science Classroom," for each participant. Available from:

National Science Teachers Association
1742 Connecticut Avenue, N.W.
Washington, D.C. 20009
Stock No. 471-14750
$2.00

ADVANCE PREPARATION

Carefully review the NSTA publication, "Safety In The Elementary Science Classroom." Identify major aspects to be emphasized in reviewing the guide. Plan introduction to the topic using Teaching Aid 1.

TEACHING SEQUENCE

1. Introduce the activity by summarizing information provided in Teaching Aid 1, Supplemental Information on Safety in the Science Classroom.
2. Distribute copies of the guide, "Safety In The Elementary Science Classroom." Review the guide, highlighting major areas of concern from your experiences.
3. Allow time for participants to discuss problems related to safety from their experiences and possible preventive measures.

SUPPLEMENTAL INFORMATION ON SAFETY IN THE SCIENCE CLASSROOM

Marshall Longmire
Jackson State University

Elementary school teachers have long been responsible for the safety and well-being of students entrusted to their care. Perhaps because this concept has become so much a part of a teacher's daily responsibility, it is sometimes taken for granted. Consequently, care and conscientious attention to detail are more and more frequently omitted.

Teachers must plan for student safety. Such planning requires foresight and insight. Teachers must be aware of the potential hazards in any given activity or situation. Moreover, care must be exercised in planning lessons to foresee and eliminate situations in which an injury might occur. By attempting to identify hazardous situations, teachers become more aware of such situations. Certainly every teacher would caution students when boiling water on the stove; perhaps students would not be allowed to do it at all. We can recognize such a situation as an obvious potential hazard: the student might be burned.

To decrease the likelihood of injury, teachers could eliminate the manipulation of materials. However, that would defeat our purpose in science education. More logically, plans could be made in such a way as to identify hazards in advance. Alternative methods to accomplish the same goal, without the hazard, could be substituted.

Students should be taught proper techniques in handling and caring for materials and equipment. Most teachers make rules for proper conduct in the classroom and designate specific procedures to be followed in certain situations. Likewise, teachers should make rules concerning the use and handling of science materials and equipment. Perhaps a specific area of the room can be designated as the science area. Rules concerning the use of selected equipment (such as the hot plate) might specify that the equipment will be used only when the teacher is assisting the student. Reminders can be posted in the form of charts and cartoon-like posters.

A technique of utmost importance in avoiding pupil injury is to give clear, complete directions each time an activity is to be performed. Do not assume your students will remember even general directions or rules from one day to the next or from one manipulation to the next. Give directions and repeat rules each time.

With the growing practice in our society of people entering lawsuit against someone for minor, or maybe even imagined, injuries or slights, teachers need to develop an awareness of such action and protect themselves against it. Pupils can and do bring lawsuits against teachers for injury. The best defense is to make sure that no students sustain injury in your class. However, no one can absolutely insure against injury. A student will occasionally become injured even with the careful planning. Without careful planning, a teacher could be found negligent and perhaps legally liable for the student's injury. Teachers must guard against injury and negligence.

It is not the purpose of this section to scare elementary teachers, only to build awareness. Prevention is so much better than regret. Therefore, plan lessons carefully; think about safety needs; caution students; and keep hazards to a minimum. Do not become careless or be lulled into a sense of false security.

In summary, here is a set of some safety items which should be implemented:

1. Make and enforce rules.
2. Label dangerous substances and store them out of the reach of children.
3. Avoid hazardous situations.
4. Remind students regularly of safety rules.
5. Supervise students at all times.
6. Identify potential safety hazards in the classroom.
7. Use alternate methods to reduce hazards and to prevent injury.
8. Plan carefully and thoroughly.
9. Give explicit directions each time an activity is conducted.
10. Locate and train in the use of these emergency areas:
    a. Exits
    b. Fire extinguishers
    c. Fire alarms
    d. First aid kits
    e. Fire escape routes
    f. Running water sources

NOTE: A flip chart safety guide has been developed by the National Science Teachers Association, called "Safety in the Elementary Science Classroom." This guide provides an array of measures and suggestions on "what to" and "how to" provide for a safe environment in the elementary science classroom.

Order from:

National Science Teachers Association
1742 Connecticut Avenue, N.W.
Washington, D.C. 20009
Stock No. 471-14750
$2.00

Teaching Aid 1, Cont.

APPENDIX A

MAGNETS

Unit 8
Magnets and Electricity

Unit Overview

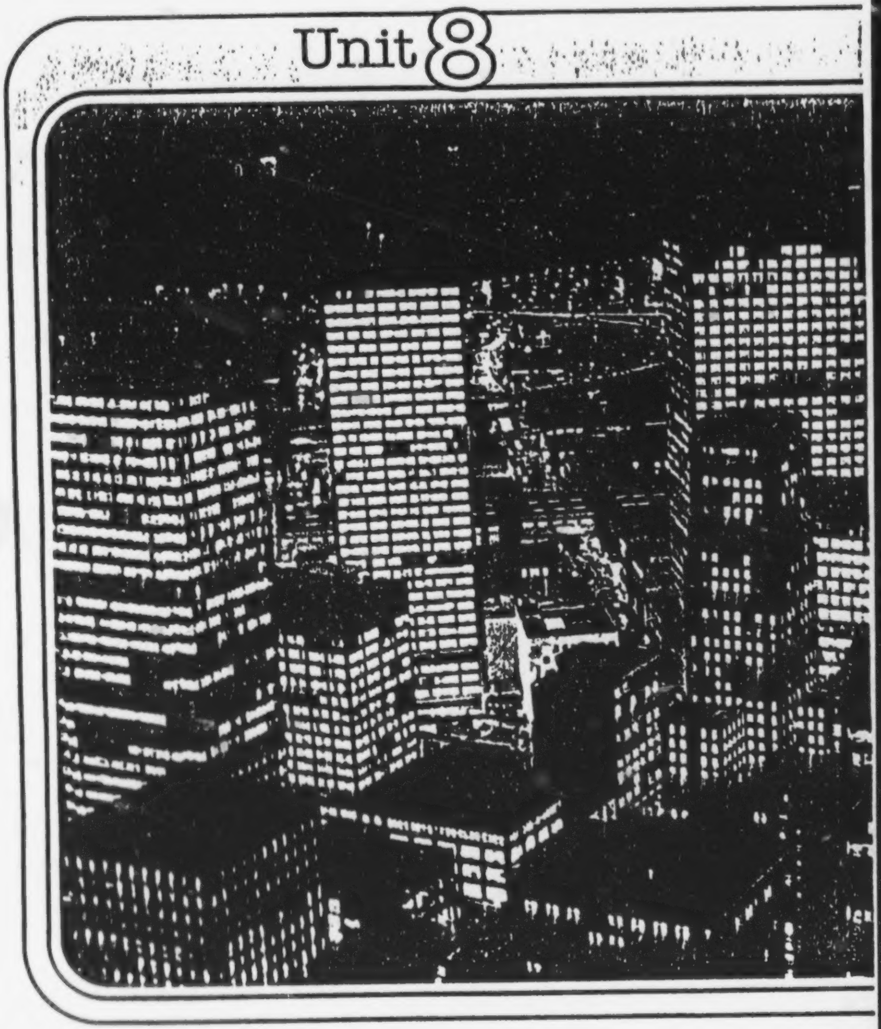
Magnetism is a unique property of matter. Persons of any age can physically manipulate magnets and feel their attracting and repelling forces. However, it is much more difficult to understand the concepts of magnetic poles, fields, and lines of force which are necessary for an explanation of magnetism. At this age level, it is necessary to provide concrete experiences rather than develop magnetic theory.

Almost all household devices use electricity. The refrigerator, toaster, blender, lights, television, and stereo are examples. In many homes even the heat is electric. Gas furnaces also use electricity to operate the fan and control the flame. Since nearly everything in a home uses electricity, if the power were shut off even the heat might go off. We would be left with fires and candles for heat and light. This may be a good time to discuss conservation with the students.

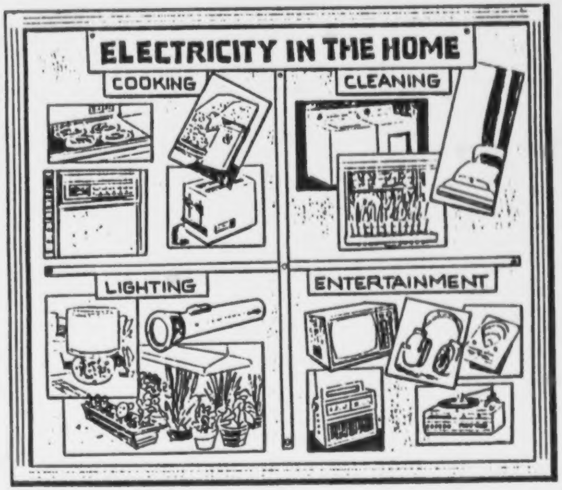
Planning Ahead

- Obtain magnets for use with this unit.
- Check your supply of flashlight batteries. Discard those that are weak.
- You will need bulb holders and switches. A junior or senior high science lab would be a source of these items.
- Some old magazines would be useful to help complete the bulletin board suggestions.

Permission was granted by Charles E. Merrill Publishing Company to include Chapter One, "Magnets," from Unit Eight in the Accent On Science, Teachers' Annotated Edition, Grade 4 in this manual.



Magnets and Electricity



Bulletin Board

Cut out pictures depicting household uses of electricity. Have students suggest different ways of classifying each use. Make labels and have students place pictures on the appropriate section of the bulletin board. Encourage students to invent several different classification themes.

Introducing the Unit

Refer to the bulletin board suggestion to have students brainstorm the different ways electricity is used in your community. List these ideas on the chalkboard. Have each individual student rank-order the uses from most to least important. Discuss in class the varying points of view. Point out that it is difficult for people to completely agree on matters of this type. (To simplify, you may wish to merely have students classify each use as very important, somewhat important, or not very important.)

Chapter One
Magnets

Time Allotment: Allow four to five days to complete this chapter.

Objectives

Students should be able to:

Lesson 1

1. **operationally define a magnet.**
2. **explain how to magnetize an object.**
3. **indicate and explain the similarities and differences between temporary and permanent magnets.**

Lesson 2

4. **identify the north and south seeking poles of a magnet.**
5. **demonstrate that unlike poles attract and like poles repel.**
6. **draw a picture showing a magnetic field around a bar magnet.**

Lesson 3

7. **classify and explain some common uses of magnets.**
8. **infer the importance of magnets.**

Key Science Words

magnet
lodestone
poles
attract
repel
magnetic forces
magnetic field

Materials List

See page T36

Introducing the Chapter

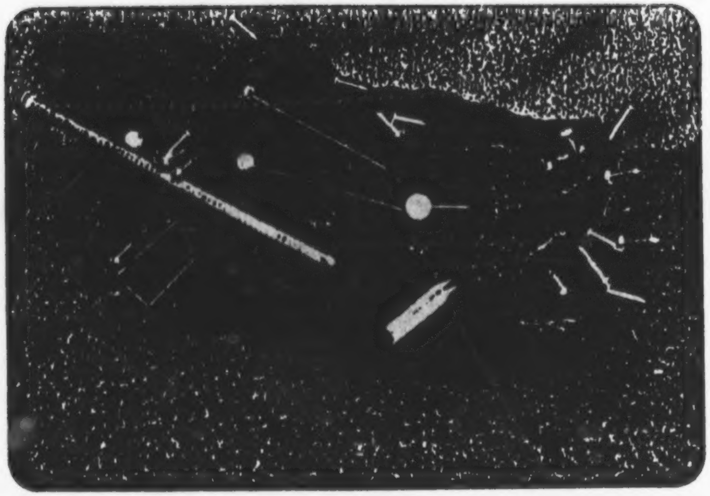
Refer to the chapter opening photograph to initiate a discussion of magnets and magnetism.

Permission was granted by Charles E. Merrill Publishing Company to include Chapter One, "Magnets," from Unit Eight in the Accent On Science, Teachers' Annotated Edition, Grade 4 in this manual.

Chapter One
Magnets

1. A magnet is an object with [illegible]
3. Accept all [illegible]

What is a magnet? What special property does a magnet have? How do you use magnets?



A very long time ago a mineral was found that had a special property. When it came in contact with certain metals, the mineral and the metals would stick together. At first, people thought this property was some kind of magic.

Magnets

What people thought was a magic stone was really a magnet. A magnet is an object that is able to attract some materials. A natural magnet is called a **lodestone** (LOHD stohn). Lodestones were the first magnets known to people.

Lesson 1 Making a Magnet

pages 253-255

This lesson explains how magnets are made. It also illustrates some properties of magnets.

Science Background

A lodestone is a naturally occurring mineral with magnetic properties. Magnets can be made from alloys of iron, nickel, and cobalt. A magnet is formed when the molecules of a substance are aligned in the same direction. Rubbing a magnet in one direction on a piece of steel will cause some of the molecules in the steel to align themselves, thus creating a magnet.

Teaching the Lesson

1. Display some toys that use magnets as well as other common devices with magnets. Discuss the behavior of magnets when brought near one another.
2. If possible, obtain a lodestone and demonstrate its magnetic properties to the class. Explain and discuss the definitions of magnet and lodestone.
3. If available, distribute some magnets and have students explore their characteristics. Have students identify the types of substances attracted to the magnet. Make two lists on the chalkboard—those attracted and those not attracted by a magnet.

4. Refer to the photographs on this page to initiate a discussion of how to make a magnet. In the first example, stress that it would take a long time for the nail to become magnetized.
5. Demonstrate how to magnetize a nail using a bar magnet. If materials are available, have students magnetize the nails themselves. Point out that sometimes people use this technique to magnetize small hand tools, especially screwdrivers. Answer the text questions. How did you do it? *Answers will vary. Students will probably indicate they used another magnet to magnetize the object.* How long did the object stay magnetized? *Answers will vary.*

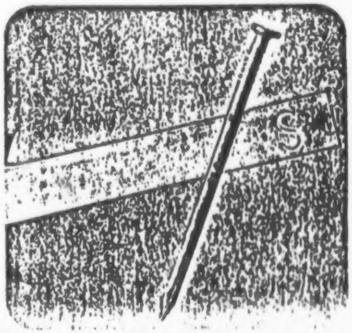
Making a Magnet

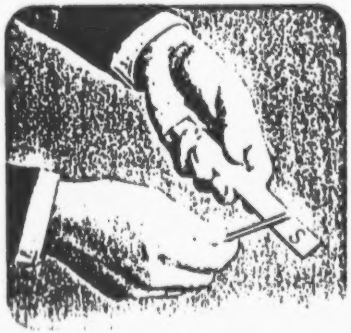
A lodestone is not the only kind of magnet. Certain metals can be magnetized (MAG nuh tized), or made into magnets. Iron, nickel, and cobalt can be magnetized. Most magnets are made of a mixture of these metals.

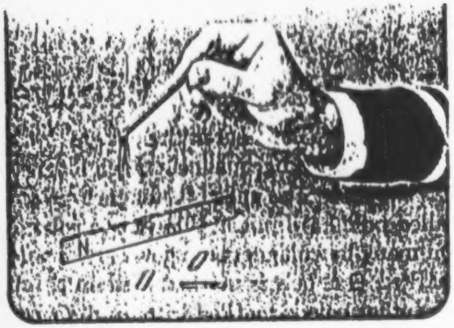
Suppose you want to magnetize an iron nail. You can use a magnet to make a magnet. One way is to place the nail in contact with a magnet. After a while, the nail will become magnetized.

Another way to magnetize the nail is to stroke the nail with the magnet. Each stroke must be made slowly in one direction. After many strokes, the nail will become magnetized.

You may have magnetized an object. How did you do it? How long did the object stay magnetized?



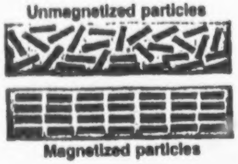




Suppose you use a magnet to magnetize a nail. You stroke the nail many times with the magnet. Then you test the nail. It picks up some paper clips. The nail is now a magnet. Its appearance has not changed. How did it become a magnet?

The change that took place in the nail is one that cannot be seen. A nail is made of tiny particles of matter. They are too small to be seen. The particles are not arranged in any special order. They point in many different directions. When you stroke the nail with a magnet, the particles line up. When the particles all point in one direction, the nail is magnetized.

The particles of a permanent (PURM uh nunt) magnet stay lined up for a long time. Other magnets, such as the nail, lose their magnetic properties quickly. The particles of a temporary (TEM puh rer ee) magnet do not stay lined up. Why do temporary magnets lose their magnetic properties? How could you make them magnets again?



6. Answer the text question. How did it become a magnet? *The nail was magnetized because it had been rubbed with a magnet.*

Optional Strategy

- Have students magnetize a nail by rubbing it with a bar magnet. Have students investigate the relationship between the number of times they stroke the nail and the strength of the magnetized nail that results. Measure the strength of the magnetized nail by how many paper clips it will pick up.

7. Refer to the picture on this page to explain how the particles (molecules) in magnetized matter tend to point in the same direction. Answer the text questions. Why do temporary magnets lose their magnetic properties? *Because the particles of matter do not remain pointed in the same direction.* How could you make them magnets again? *They could be remagnetized by rubbing them in one direction with a magnet.*

Reinforcement

- Review the types of substances that are attracted by a magnet. Have students use a magnet to separate a mixture of USA and Canadian nickels. The Canadian nickels contain more pure nickel and are attracted by the magnet.

Enrichment

- Use magnets to make a magnetic puppet or other toy.
- Have students make a temporary magnet and determine its strength by determining the number of paper clips it will lift. Using paper clips as a measure, have students determine the effect hammering on the magnet has on its magnetic properties. (Hammering can weaken or destroy magnetic properties.)

Lesson 2 Magnetic Behavior

pages 256-259

The behavior of magnets and magnetic fields are explored in this lesson.

Science Background

Bar magnets suspended by a string will orient themselves in a North-South direction. The same pole of the magnet always points North and the other South. Thus, magnets are said to have both north and south-seeking poles. Be sure that the students understand that the north-seeking pole is also the North pole. This leads to the conclusion that the polarity of magnetic North is South.

Magnets are surrounded by a pattern of force lines called a magnetic field. This magnetic field is invisible, odorless, tasteless, and silent. The field can be revealed by placing a sheet of paper over the magnet and then sprinkling iron filings on the paper. The iron filings align themselves parallel to the magnetic lines of force. This pattern is a representation of the magnetic field.

The Earth has a magnetic field. It is the interaction of the magnet and Earth's magnetic fields that causes the magnet to point North. Interaction of two force fields is also responsible for like poles of a magnet repelling each other and unlike poles attracting.

Teaching the Lesson

1. Refer to the photograph on this page and/or display a bar magnet and explain that the ends of the magnet are called poles. Stress that all magnets have two poles, one marked N and the other marked with an S. Answer the text question. What do you think the pole marked with an S is called? *The pole marked with an S is called the south-seeking pole.*
2. Suspend a bar magnet from a string. Be sure it can swing freely. Students should observe that the pole marked N points toward the North. Answer the text question. Which way does the pole marked S point? *The pole marked S points toward the South.*
3. Use another bar magnet and bring it near the poles of the suspended magnet. Demonstrate attraction and repulsion. Help students infer the concept of like poles repelling and unlike poles attracting one another. Answer the text question. What happens when two south poles come together? *All like poles will repel each other.*

Optional Strategy

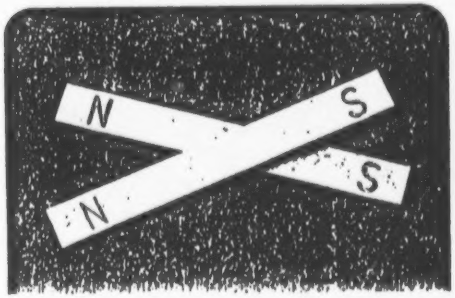
- Some students may correctly infer at this time that the North pole of the Earth is in fact a magnetic south pole since it attracts the N pole of a bar magnet. You may choose to discuss this point.

How Magnets Behave

Look at the magnets in the picture. They are called bar magnets. Each magnet has two ends. The ends of a magnet are called **poles**. All magnets have two poles. On many bar magnets the poles are marked. One pole is marked with an N. The other pole is marked with an S. The pole marked with an N is called the north-seeking pole. What do you think the pole marked with an S is called?

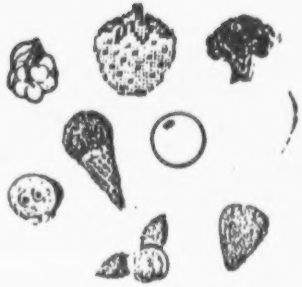
Suppose you hang a bar magnet from a string so it is free to swing. The pole marked N will point North. Which way does the pole marked S point?

Suppose you bring another magnet near the one hanging from the string. The north pole of one magnet will **attract** or pull toward the south pole of the other magnet. Two north poles **repel** or push away from each other. What happens when two south poles come together? This behavior of magnets is always the same. Like magnetic poles of a magnet repel each other. Unlike magnetic poles attract.



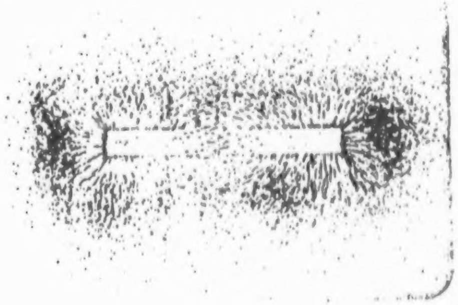
Magnets can be different sizes and shapes. They can be made of different materials. But, all magnets behave alike.

Magnets have pushing and pulling forces that are called **magnetic forces.** Magnetic force is not spread evenly through a magnet. A magnet's force is greatest at its poles. The two ends of a bar magnet have more magnetic force than its middle. Describe some magnets you have seen. Where was their magnetic force the greatest?



Magnetic Field

The area around a magnet where the magnetic force acts is called the **magnetic field.** The magnetic field cannot be seen. It makes no noise. It has no odor or taste. You cannot touch it. How can you study a magnetic field?



4. Point out that magnets are not all the same shape. Discuss the meaning of magnetic force. Note that the magnetic force of any magnet is the greatest at the poles. Explain that the area near a magnet affected by the magnetic force is known as the magnetic field. The magnetic field is not visible. (You may wish to review the concept of force in *Accent on Science*, Level Three, Unit Two.) Answer the text question. Where was their magnetic force the greatest? *It was greatest at the poles.* How can you study a magnetic field? *Since it cannot be seen directly, we must study what is done by the force of a magnetic field.*

Meeting Needs: Adapt this concept for special students by making them a permanent model of a magnetic field. Use an electric skillet to melt a bar of paraffin (the kind used to seal jars of homemade jelly). The lowest heat, 46°C (115°F), will work. Dip a sheet of construction paper into the paraffin so it is coated on both sides. Quickly pull it out and let the excess paraffin drip into the skillet. After a few seconds, lay the paper on a desk top to cool and dry for one minute. DO NOT TOUCH. Give the treated paper to your special students. Let them cut a strip of self-sticking weather strip tape the length of their bar magnet and tape it to their paraffin paper. Now place the paper over the bar magnet so the magnet is directly under their weatherstrip tape. Gently sprinkle iron filings on the paper. Now the teacher should turn on a heat lamp and carefully hold it about 15 cm over the iron filings until they look moist. (The filings will heat up first and melt a little of the paraffin around them.) This takes only a few seconds. Remove the heat lamp and allow the paraffin to cool and harden. Now the student has a permanent model to touch and observe. You may choose to use only a half sheet of paper. You may also have to move the lamp around over the paper to cover all the filings. DO NOT OVERHEAT. The paraffin will turn brown when overheated. STUDENTS SHOULD NOT OPERATE THE HEAT LAMP.

This activity gives students an opportunity to observe a magnetic field. The observation is in two dimensions only.

Activity

How Can You Find a Magnetic Field?

Time Allotment: Allow two 45-minute science periods to complete this activity.

Objectives

Students should be able to:

1. draw a picture of the magnetic field around a magnet.
2. understand that magnetic fields are invisible.
3. know that the iron filings only show where the magnetic field is.
4. describe changes in the shape of magnetic fields that are attracting or repelling each other.

Preparation Suggestion

- Have the students cover their work area with newspapers. Pour the iron filings into a salt shaker. This makes it much easier for the students to spread the filings evenly on the paper covering the magnet. You may wish to use enough shakers so that each student has one.

Teaching Suggestions

- Gently tap the paper after the iron filings are sprinkled over the surface. This helps arrange the filings in the pattern making the lines of force more visible.
- You may wish to spray several light coatings of hair spray over the pattern of iron filings. This will cause them to stick to the paper making a more permanent record of the magnetic field.

What did you learn?

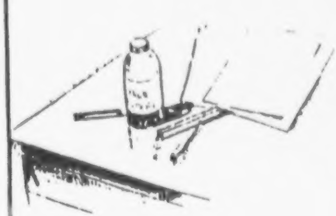
1. Most of the iron filings collected around the poles of the magnet.
2. Answers will vary.

Using what you learned:

1. This question is meant to be a prediction. Have the students draw their predictions before trying the next step. Then they can compare their prediction with the actual outcome.
2. Hint: Use a question lead-in before they predict: What happens as unlike poles of two magnets approach each other? How might this affect the magnetic lines of force? The result is the opposite effect. There are lines of force between the two poles.

Activity

[illegible]



How Can You Find a Magnetic Field?

What to use:

2 bar magnets
4 sheets of paper
iron filings
metric ruler

What to do:

1. Trace a bar magnet on paper. Mark the poles. Save this paper.
2. Put the magnet on your desk. Cover it with a blank sheet of paper.
3. Gently sprinkle iron filings on the paper. Tap the paper lightly with your finger. CAUTION: Do not let the iron filings touch the magnet or get into your eyes.
4. Draw the pattern formed by the iron filings on the paper you saved.

What did you learn?

1. Where did most of the iron filings collect?
2. How far out from the magnet did the pattern show up?

Using what you learned:

1. If you place two magnets N to N about 1 cm apart, how will the magnetic field look?
2. How will the magnetic field look if the magnets are placed N to S?

You can feel the effects of a magnetic field. You can feel the push or pull when you bring two magnets together. You feel the magnetic field when you bring an object, such as a paper clip, close to a magnet. As you move the paper clip closer to the magnet, you reach a point where you can feel the magnet pulling the clip.

Although you cannot see a magnetic field, you can see its effect. When iron filings are placed near a magnet, they form a pattern. This pattern shows the shape of the magnetic field. The pattern seems to end at the surface of the magnet. You cannot see it, but the magnetic field goes through the magnet also.

Some Uses of Magnets

Describe some magnets you have seen. What different shapes did they have? How were the magnets used? What two ways were the magnets alike?

There may be a number of ways magnets are used in your home. Perhaps a magnet holds the refrigerator door shut. Some cabinet doors are held shut with magnets also. You may use magnets to attach notes, lists, and drawings to refrigerator doors or magnetic bulletin boards. Where might a magnet be on an electric can opener? What other ways are magnets used at home?

Reinforcement

- Secure a magnet to a desk or other object. Tie a light string or thread to a pin. Slowly move the pin away from the magnet. Held by the thread at one end and the magnetic field at the other, the pin appears to be almost suspended in air.

Enrichment

- Have students make a temporary magnet. Have students determine which end of their temporary magnet is a N and which is a S pole.

Lesson 3 Uses of Magnets page 259

Common, practical uses of magnets are discussed in this lesson.

Science Background

There are virtually thousands of uses for magnets broadly affecting the lives of most people. Household items from cabinet latches to can openers rely on magnetic force for their operation. Industry and medicine have a wide range of uses for this force which cannot be seen, felt, or has no odor.

Teaching the Lesson

1. Use the text questions as well as photographs to initiate a discussion of magnets. Review concepts developed to this point. In addition, discuss importance of simple magnets. Answer the text questions. What different shapes did they have? *Magnets can be almost any shape. The most common are either flat discs, bars, or horseshoe-type magnets.* How were the magnets used? *Answers will vary. Most magnets are used to hold another object.* What two ways were the magnets alike? *Accept all reasonable answers. Some answers might be that the magnets had two poles or the magnetic field was strongest at the poles.*
2. Create a list of places magnets can be found in the home. Some examples are the electric motors found in clocks, mixers, food processors, electric can openers, electric drills, saws, circuit breakers, cabinet door latches, radios, TV, stereo, and decorator items. Answer the text questions. Where might a magnet be on an electric can opener? *Most can openers use a magnet to hold the top of the can, thus preventing it from falling into the can when it is cut. (Some students may realize that magnets are also used in electric motors.)* What other ways are magnets used at home? *Accept all reasonable answers.*

Reinforcement

- Have students do a home magnet survey. Compare their findings in class.

Enrichment

- Have students research industrial uses of magnets. Pool their findings.

Science Accent

Most of us think of magnets as the colorful decorator types found on refrigerator doors. If you were to take a survey of the magnets in use around you every day, you would probably be surprised.

This feature presents some uses for magnets that your students may not have been aware of. You can lead your students from a discussion of the examples to an exploration of other uses for magnets.

Teaching Suggestions

- Discuss how people use magnets. Refer to the list of uses for magnets in the home developed on page 259. Expand this list as necessary to include uses in industry, navigation, health, and play. Have students develop a classification system for the list of uses. Discuss the use of compasses. For practice, have students hide "treasures" and then write "treasure maps" using compass directions. Have students challenge one another with their maps.
- If possible, take apart an old electric motor, allowing students to observe the magnets.
- Explain how magnets could be used to remove some metal contaminates. Answer the text questions. What might happen if metal particles would mix with food or chemical products? *The food or product would be ruined. It would also be unsafe.* How might a magnet be useful to a treasurer hunter if gold does not stick to a magnet? *A compass would help you locate the treasure by using a map. Also, a magnet would be attracted to metals that would indicate the presence of a ship, parts of a "treasure" chest, or other such containers.* How would a magnet be useful to a doctor who is trying to remove a steel splinter? *The magnet (shown in the picture) will allow a doctor to remove the splinter without surgery.*

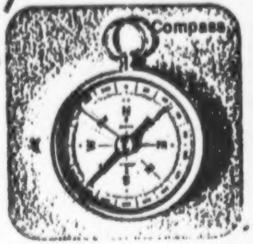
Reinforcement

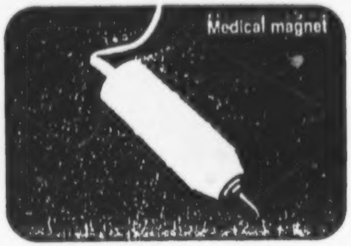
- Set up a compass course on the schoolyard or other large area. Have students follow a given set of directions. Discuss how well students are able to arrive at a set destination following different sets of directions and therefore a different path.

Enrichment

- Obtain a metal finder. Have someone explain to the class how it is used.

Science Accent





A Variety of Uses

Most of the time we think of magnets as brightly colored little shapes we use to attach drawings and notes to the refrigerator door. People use magnets to do many things.

Bar magnets are used in compasses. A compass is an object used by travelers to determine direction. The needle in a compass is positioned so it can turn freely. The needle is usually a magnet. The needle always points north. By knowing where north is, a traveler is able to find other directions.

Bar magnets can be bent into a horseshoe shape. Horseshoe magnets are used where a strong magnetic field is needed in a small space. These magnets are used in the motors of some toy cars.

Large industries use magnets. Magnets can be used to separate valuable metals from other matter. In other industries, magnets are used to pick up small pieces of metal that rub off machinery. This helps keep the machinery clean. Clean machinery breaks down less often.

In the food and chemical industries, magnets keep metal particles from mixing with the products. What might happen if metal particles would mix with food or chemical products?

Magnets have been used from searching for underwater treasure to removing a steel splinter from an injured person's eye. How might a magnet be useful to a treasure hunter if gold does not stick to a magnet? How would a magnet be useful to a doctor who is trying to remove a steel splinter?

Sometime you might want to take a magnet survey. You might be surprised to learn how many magnets you use every day.

Chapter Review

Summary

- A magnet is an object that is able to attract some materials.
- A lodestone is a natural magnet.
- All magnets have two poles.
- Magnets have pushing and pulling forces called magnetic force.
- Unlike magnetic poles attract and like magnetic poles repel.
- The area of force around a magnet is called the magnetic field.

Science Words

magnet
lodestone
poles
attract
repel
magnetic forces
magnetic field

Questions

1. What are two properties of a magnet?
2. What behavior of magnetic poles is always the same?
3. Where is a magnet's force strongest?
4. How can you see the effects of a magnetic field?
5. Describe two ways an object can be magnetized.
6. What are two household uses of magnets?
7. How can you feel the effects of a magnetic field?
8. What is a lodestone?

Evaluation: Chapter Review

Summary

- Have the students make large poster drawings as examples of each summary statement. Hang the posters in your room or in the hall outside your room.

Science Words

- Design (or have several students design) a word search puzzle that contains each of the science words. Have students locate, define, and use each word in a simple sentence.

Questions

1. Answers may vary. Students may suggest:
   (a) like poles repel.
   (b) unlike poles attract.
   (c) all magnets have two poles.
   (d) all magnets have a magnetic field.
   (e) the magnetic field of a magnet is greatest at its poles.
   (f) magnets can attract some substances, and so on.
2. Like poles always repel while unlike poles always attract.
3. A magnet's force is strongest at the poles and weakest in-between the poles.
4. Answers may vary. Students may suggest placing a magnet under a sheet of paper and spreading iron filings on top.
5. Objects may become magnetized if they stay in the same position for a very long time. Objects may also become magnetized if they are rubbed with another magnet.
6. Students might answer: decorative magnets on refrigerators or bulletin boards, refrigerator doors, cabinet latches, or electric can openers. Accept all correct answers.
7. You can feel the push or pull whenever you bring two magnets together. You can also feel the magnetic field when you bring an object close to a magnet.
8. A lodestone is a natural magnet.

ENRICHMENT

Unit 8 Chapter One

NAME ____________________ Use after page 260.

GUESS WHAT OBJECT I AM

The objects described below either contain magnets or are themselves magnetized. Use the clues to guess what each object is. Fill in the missing letters and name the objects.

1. A carpenter might use me to hold small objects in place while doing a job. _ _ R _ W _ R _ V _ R
2. An ocean traveler would have trouble finding the way home without me. _ O _ _ _ _ S
3. Many children like to collect us. Some of us have motors containing horseshoe magnets. _ _ Y _ _ R _
4. You probably open my magnetic door many times a day when you are hungry or thirsty. R _ _ _ I G _ _ _ _ _ _
5. Doctors can use me to remove metal splinters without surgery. _ _ D _ _ _ L M _ G N _ _
6. Treasure hunters use me to locate hidden treasures. _ _ T _ _ D E T E C T O R
7. I am usually found in the kitchen. I am useful for opening sealed cans. _ _ N _ _ E N _ R

REVIEW

Unit 8 Chapter One

NAME ____________________

Circle the letter of the correct answer to complete each statement.

1. The particles of a magnet
   a. point in different directions. b. point in 2 directions c. point in 1 direction
2. When two south poles come together, they
   a. attract each other b. repel each other. c. balance each other.
3. The pushing and pulling behavior of magnets is called
   a. magnetic force. b. magnetic field. c. magnetic area.
4. Magnets that lose their magnetic properties quickly are
   a. temporary magnets. b. lodestones. c. permanent magnets.
5. The first magnets known to people were
   a. metals. b. lodestones c. bar magnets.
6. The north pole of a magnet is called the
   a. north-seeking pole. b. south-seeking pole. c. magnetic pole.
7. When unlike magnetic poles come together, they
   a. attract each other. b. repel each other. c. balance each other.
8. Circle the letters of the names of metals that can be magnetized.
   a. aluminum b. copper c. cobalt
   d. iron e. nickel f. lead
9. List four uses of magnets at home and school.
   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________

TEST

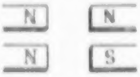
Unit 8 Chapter One

NAME ____________________

Fill in the blanks with the correct answers.

1. What is a magnet? ____________________
2. Explain two ways you could magnetize a nail.
   a. ____________________
   b. ____________________
3. a. How are permanent and temporary magnets alike? ____________________
   b. How are permanent and temporary magnets different? ____________________
4. Look at the drawings. Tell whether the poles will attract or repel each other.

____



____

5. How could you identify the north and south poles of a magnet that is not marked N and S? ____________________
6. Where is the magnetic force greatest on a bar magnet? ____________________
7. What are three everyday uses of magnets?
   a. ____________________
   b. ____________________
   c. ____________________
8. Draw a picture showing what the magnetic field around this magnet would look like.

Note:

The answers to the questions in the teacher's edition were in red ink and did not copy well.

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APPENDIX B - USMES MATERIAL

INTERMEDIATE HOW TO SERIES

GRAPHING

Make a Histogram
Make a Line Graph
Use Graphs to Compare Two Sets of Data

OSU

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DATE: January 22, 1986

TO: Iva Brown
The Univ. of Southern
Mississippi
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Southern Station
Box 8378
Hattiesburg, MS 39406-8378

FROM: Dr. Robert W. Howe, Director Robert W. Howe

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RWH/bjb
Enclosure

College of Education
Department of Educational Theory and Practice
Science and Mathematics

"HOW TO"

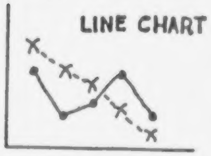
USE GRAPHS TO COMPARE TWO SETS OF DATA

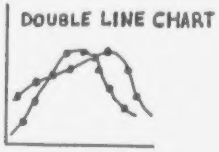
WHY USE GRAPHS?

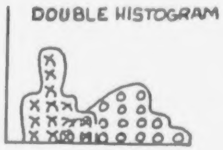
Maybe you have collected two sets of data and you want to compare them. Each set of data may have lots of numbers. It is confusing to try to look at all of the numbers at once. There is an easy way to look at all of the numbers. You can make a graph. The graph will be a picture of both sets of data. You can look at both sets of data without getting mixed up.

WHAT KINDS OF GRAPHS CAN YOU MAKE?

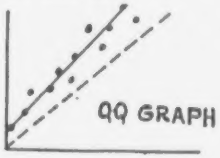
There are two types of graphs you can make to compare two sets of data. One type of graph has two lines on it. These graphs are like that.

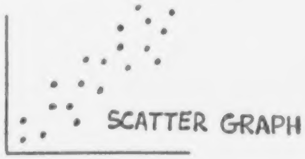






The other type of graph has just one line or a scatter of points. These graphs are like that.





HOW DO YOU DECIDE WHICH GRAPH TO USE TO COMPARE YOUR TWO SETS OF DATA?

There is no simple rule. You will have to think about what kind of data you have. You will have to think about what you want to find out. You may even want to try making several different graphs for your data.

This booklet will help you do these things. The booklet will show you examples of the five graphs that you can make. It will help you choose a graph to compare your data. It will show you how to use graphs to get the information you need.

WHAT'S INSIDE

PAGE
DECIDING WHAT KIND OF DATA YOU HAVE.......................................
MAKING A LINE CHART.. 2
MAKING A DOUBLE LINE GRAPH.. 3
MAKING A DOUBLE HISTOGRAM.. 7
MAKING A Q-Q GRAPH.. 9
MAKING A SCATTER GRAPH.. 12
HOW TO PICK A GRAPH FOR YOUR DATA.. 17

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DECIDING WHAT KIND OF DATA YOU HAVE

Use this page to decide what kind of data you have. Then read the examples to decide which graph to use to compare your data.

Look at the data you have collected. Your data could be numbers or they could be numbers and words. WHAT ARE THE PARTS OF YOUR TWO SETS OF DATA?

- A list of words? They could be lists of people or tools or foods or months. These can be called SEPARATE ITEMS.

PEOPLE
SUE
JIM
MARY
JOE
KAY

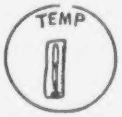
- Numbers? They could be numbers of cars or numbers of children or numbers of times something happens. These can be called NUMBER COUNTS.

NUMBER OF CHAIRS

NUMBER OF TIMES

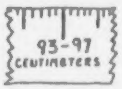
NUMBER OF PEOPLE

- Times or temperatures or heights or weights? These can be called MEASUREMENTS. You can tell that they are measurements because each number will have a unit, like degrees or centimeters or grams.



- Sometimes you may want to put your measurements together in clumps, like 8-12 seconds or 41-50 grams or 93-97 centimeters. Then the measurements can be called GROUPED MEASUREMENTS.

8-12
SECONDS

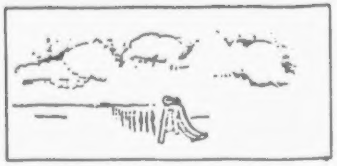


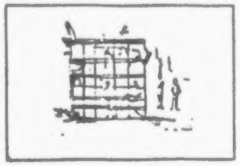
MAKING A LINE CHART

You may want to compare the same type of data collected at two different times or places or from two different groups of people.

- *You may want to compare the morning traffic in front of the school for a week with the afternoon traffic for the same week.*
- *You may want to compare the favorite flavors of soft drinks for two different grades.*
- *You may want to compare which kind of playground equipment younger and older children like*

If you are trying to decide something like this, your data will be SEPARATE ITEMS and NUMBER COUNTS. You can make a LINE CHART. Then you can look at all the data at once.



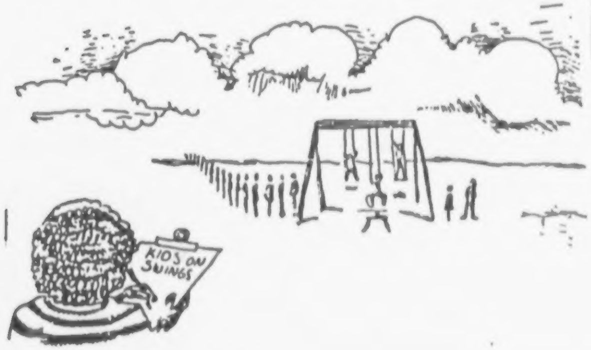


A LINE CHART will make it easier to decide when you need to pick a favorite thing for several groups. That's what Eric and his friends find out in this story.

Eric's class has raised enough money to buy a new piece of equipment for the school playground. But the class can't agree on what to get because everyone has a different idea. Eric and two of his friends, Jennifer and Tom, want to find out which piece of equipment is used most. They think that this will help the class to decide.

First, they go to the grade 1-3 recess. Jennifer counts the number of children using the swings. Tom counts the number of children using the slides. Eric counts the number of children using the monkey bars. Their data look like this.

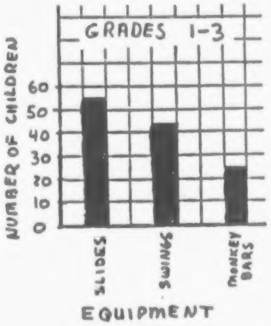
EQUIPMENT USED (Grades 1-3)	APRIL 2
EQUIPMENT	NUMBER OF CHILDREN
Slides	55
Swings	42
Monkey Bars	24

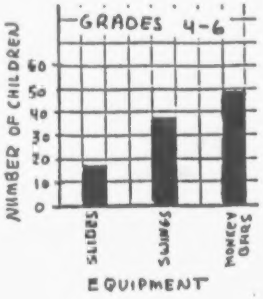


Then they go to the grade 4-6 recess and do the same thing. They count the number of children using the slides, swings, and monkey bars. The grade 4-6 list looks like this.

EQUIPMENT USED (Grades 4-6)	APRIL 2
EQUIPMENT	NUMBER OF CHILDREN
Slides	18
Swings	38
Monkey Bars	49

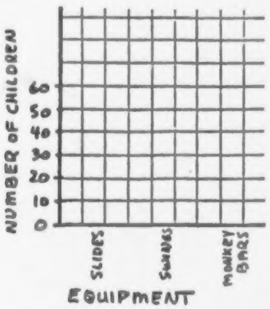
Eric, Tom, and Jennifer know what to do next. They make a bar graph for each set of data. The bar graphs look like this.





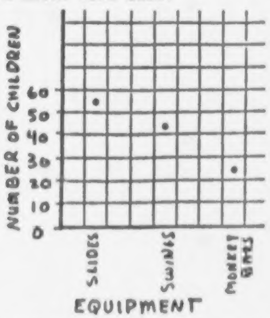
They look at the graphs. They see that grades 1-3 use the slides most, but that grades 4-6 use the monkey bars the most. "What should we do now?" asks Tom. "The different grades like different types of equipment. We still don't know which piece of equipment to buy."

Eric has an idea. "We can make a line chart with our data. Maybe when we see our data on the line chart, it will help us to decide. We can use our bar graphs to make the line chart. We made the scales and labels on the two bar graphs the same; so a line chart will be easy to make." He puts the same scale and labels on another piece of graph paper. The graph looks like this.



"Now we can put marks on the graph showing where the tops of the bars for each bar graph go. We can use red dots to show where the tops of the bars go for grades 1-3, and green Xs to show where the tops of the bars go for grades 4-6. That way we can tell them apart."

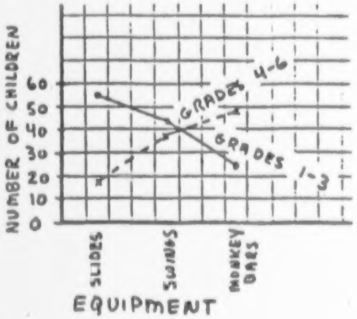
Eric puts the red dots first. He puts one dot at 55 in the middle of the column marked SLIDES. He puts another dot at 42 in the middle of the column marked SWINGS, and a third dot at 24 in the middle of the column marked MONKEY BARS. Now the graph looks like this.



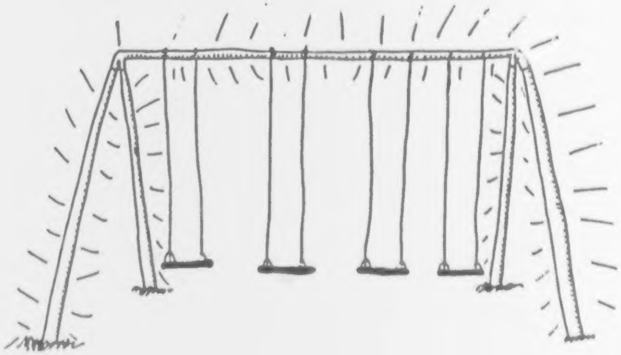
"This graph looks just like the bar graph for grades 1-3 with the bars melted away," says Tom. "Now I suppose we can put on the green Xs. May I do it?"

Tom puts on the green Xs. He puts a green X at 18 in the middle of the column marked SLIDES. Then he puts on the other two green Xs. "What do we do now?" he asks. "Are we finished?"

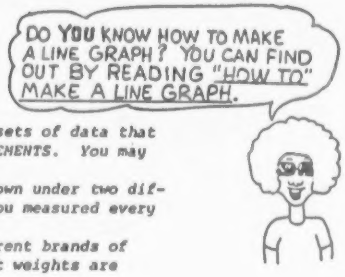
"There is just one more thing to do. We can connect each set of marks with lines," says Eric. "We can connect the red dots with a solid red line and the green Xs with a dashed green line. That will make the dots easier to see." Jennifer wants to help. She puts the lines on the graph. Then she labels each line. Now the line chart looks like this.



Jennifer looks at the finished line chart. "I think we should recommend swings," she says. "All grades use swings a lot." Eric, Tom, and Jennifer show the line chart to the class. They explain how they could tell from the graph that both groups use swings a lot even though both groups use something else more. They show the class that swings are the second-highest point on both lines. When the class votes, swings win, and so the class uses their money to buy swings.



MAKING A DOUBLE LINE GRAPH


DO YOU KNOW HOW TO MAKE A LINE GRAPH? YOU CAN FIND OUT BY READING "HOW TO" MAKE A LINE GRAPH.

Maybe you have collected two sets of data that each have two kinds of MEASUREMENTS. You may want to compare

- *the heights of plants grown under two different conditions that you measured every week*
- *the lengths of two different brands of rubber bands as different weights are attached to them*
- *the hourly temperatures for two different days*

If you are comparing two groups of the same kind of MEASUREMENTS, taken over the same time period, you can put all of your data on a DOUBLE LINE GRAPH. Then it will be easy to compare how the two groups change or grow. You will be able to decide which group grows or changes more by looking at the graph.

In this story, three children use a double line graph to decide whether they should grow their plants in the sun or in the shade.

Lula, Patrice, and Jerome are growing coleus for a plant sale. They want the coleus to grow fast. All their plants are between 6 cm and 10 cm tall. Lula and Jerome want to put all of the plants in the sun but Patrice thinks that they will grow better in the shade. They decide to put six plants in the sun and six plants in the shade. They measure the six plants in each group every four or five days. Every time that they measure, they find the mean height of the plants in each group. After three weeks, their data look like this.

PLANTS IN SUN	
NUMBER OF DAYS	MEAN HEIGHT (cm)
0	7.7
7	8.2
12	9.0
16	9.6
21	10.5

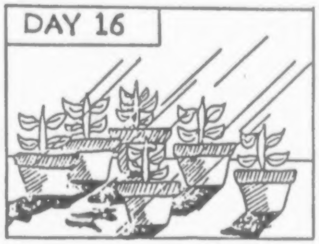
PLANTS IN SHADE	
NUMBER OF DAYS	MEAN HEIGHT (cm)
0	9.8
7	10.0
12	10.2
16	10.5
21	10.6

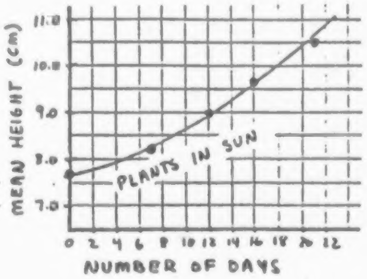
Lula, Patrice, and Jerome look at the data. They aren't sure which group grows faster. So they decide to make a graph. They think that a graph will make it easy to compare the two sets of data. But they aren't sure what kind of graph to make for their data.

Patrice says, "If we had only one of these sets of data, we could make a line graph because NUMBER OF DAYS and AVERAGE HEIGHT are both MEASUREMENTS. Should we make a double line graph?"

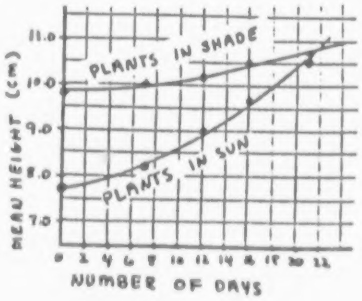
Jerome thinks this is a good idea. "Let's try it," he suggests.

The group makes a double line graph with their data. First they put on the graph the points for the plants in the sun. They draw a smooth line through or near those points. The graph looks like this.





Then they put on the graph the points for the plants in the shade. They draw a smooth line through or near those points. Now the graph is finished. It looks like this.



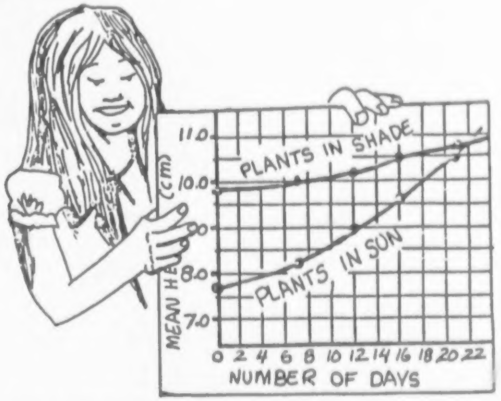
Lula, Jerome, and Patrice look at the graph. "Look!" says Lula. "The line for the plants in the shade is almost level. But the line for the plants in the sun is slanting up. It is steeper than the line for plants in the shade."

"Yes," says Jerome. "The plants in the sunlight are growing faster. They are getting taller. So the line is steep. The plants in the shade are hardly growing at all. Their line is almost level."

But Patrice is puzzled. "The line for plants in the shade started out higher. What does that mean?"

Lula knows. "When we put the plants in the groups, the plants we picked to put in the shade were taller than the plants we picked to put in the sun. So the line for plants in shade starts out higher than the line for plants in the sun. But the plants in the sun grew better anyway even though the plants in the shade had a head start."

Patrice looks at the graph again. "I learned a lot from this graph. I am going to show it to the rest of the class to prove that all of the coleus plants should be grown in the sun."



Jerome wonders whether their data really prove that coleus plants grow faster in the sun. "Maybe," he says, "the tall coleus plants just grow more slowly than the short plants." Then he checks by looking at the graph. "It looks like the plants in the sun kept growing faster even when they grew tall. But I am going to keep measuring the plants to see whether the plants in the sun keep growing fast when they get taller."

MAKING A DOUBLE HISTOGRAM

You may have collected two sets of data about the same things in two different places. You may have collected two sets of data about something before changes were made and after changes were made.

Your data may be two sets of the same type of NUMBER COUNTS and GROUPED MEASUREMENTS. Or your data may be all number counts. Your data may be two sets of the same type of NUMBER COUNTS and NUMBER COUNTS.

- *The data might be crossing times of students at two different intersections. These data are NUMBER COUNTS (number of students) and GROUPED MEASUREMENTS (crossing times).*
- *The data might be scores from spelling tests before studying the words by a new method and after studying the words. These data are NUMBER COUNTS (number of students with a given score) and NUMBER COUNTS (scores).*

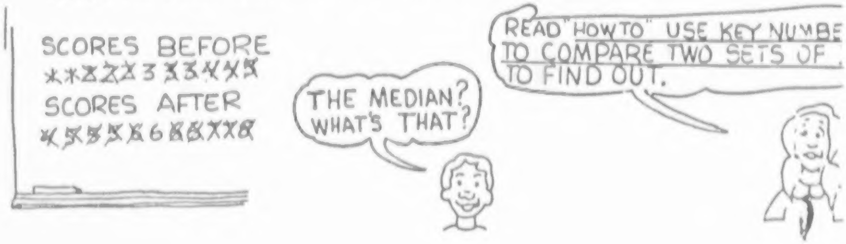
If your data are like these, you can make a DOUBLE HISTOGRAM.

Looking at the pattern of the DOUBLE HISTOGRAM may help you decide how much difference there is between the two sets of data. That's what the students in this story find out.

Rita's class is trying to find out the best way to learn spelling words. The class has divided into groups to try different ways. Rita and her group, Clem and Tyrone, have collected two sets of data on scores from spelling tests. They want to see if playing the spelling game that they made up helped one group to spell better. Their data look like this.

SCORES BEFORE PLAYING GAME	SCORES AFTER PLAYING GAME
1, 1, 2, 2, 2, 3, 3, 3, 4, 4, 5	4, 5, 5, 5, 6, 6, 6, 6, 7, 7, 8

Clem finds the middle score, or the median score for each set of data. The medians are 3 for "before" scores and 6 for "after" scores.

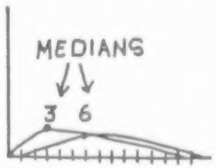


Clem thinks that this proves that the spelling game is a good way to learn, but Rita and Tyrone disagree. They think the medians are really too close to tell.

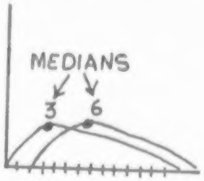
Rita says, "If the medians were further apart, we could be sure. But 6 and 3 are only 3 apart."

Tyrone says, "I know another way we can check the data to be sure. We can make histograms of our data. We can put the two histograms on the same graph. Then we can compare them with these pictures."

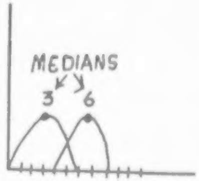
Tyrone draws three diagrams on the board to show the others what he means. The diagrams look like this.



NO REAL CHANGE

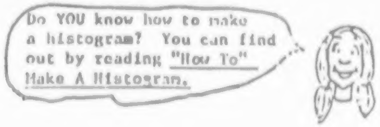


DON'T KNOW



REAL CHANGE

Clem looks at the pictures. He says, "Now I see. These are pictures of histograms. When they are apart, they show a change. When they are almost together, they show there has been no change. When they are not too close or too far apart, then we can't tell from our data if there has been a change."

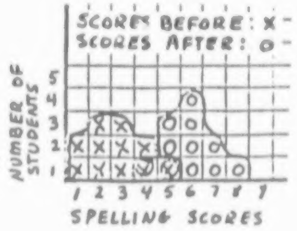

Do YOU know how to make a histogram? You can find out by reading "How To" Make A Histogram.

Clem, Rita, and Tyrone make two histograms of their data on the same graph. They use Xs for the scores before and Os for the scores after. When they are finished, the graph looks like this.

"The two histograms only overlap a little bit," says Rita.

Clem is happy. "Now we can say that our spelling game really did make an improvement in the group's spelling."

Rita's group thinks that they are finished. But just then Bill comes over to their group to ask for help. "We have some scores, too. Our medians are close. We don't know what to do."



Tyrone looks at the data from Bill's group. It looks like this.

SCORES BEFORE

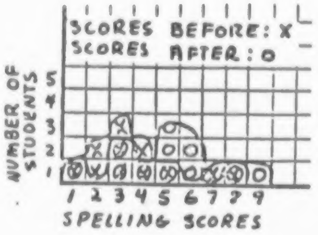
1, 2, 2, 3, 3, 3, 4, 4, 5, 7, 8
↑
MEDIAN

SCORES AFTER

1, 3, 3, 4, 5, 5, 5, 6, 6, 8, 9
↑
MEDIAN

The medians are 3 and 5. They are only 2 apart. Tyrone shows Bill's group how to make two histograms of their data on the same graph. The histograms look like this.

Bill's group is sad. The histograms don't tell them much. They are not too close or too far apart. The group can't tell whether there has been a change or not. Bill's group decides to start with some new spelling words and test their method again.

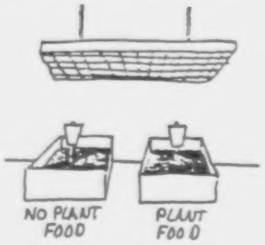


THE SPELLING GAME IMPROVED MY SCORE!
AFTER
C

MAKING A Q-Q GRAPH

A q-q graph is a special kind of graph. You can use a q-q graph to compare data that you have collected from two different places or at two different times or of two different groups of things. You can make a q-q graph to compare two sets of NUMBER COUNTS of the same things taken under different conditions or to compare two sets of MEASUREMENTS of the same things taken under different conditions. You can use a q-q graph to compare these things:

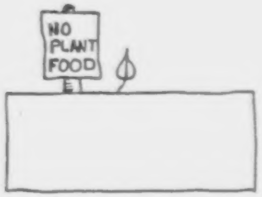
- *the number of belts made by Room 202 and by Room 205 on several different days*
- *the speeds of cars at two different intersections*
- *the heights of plants grown with plant food and without plant food.*



You can use a q-q graph to look at more than one thing about the data. It will help you see what is different about your sets of data. That's what Josette and her friends find out in this story.

Josette and her friends Randy and Carmen are planning to grow plants for a plant sale. Josette and Carmen want to buy plant food, but Randy thinks the plants will grow just as well without plant food. To settle the argument, Carmen suggests that they try an experiment. She thinks they should plant some seeds. Some of the seeds will get plant food and some will get no plant food. After the plants have come up, the group can measure the heights of the plants to see which way is better--plant food or no plant food.

Josette and Randy think that Carmen's idea is good. Josette plants 15 seeds in a box. She plans to give them 1 squirt of liquid plant food every day. Randy plants 15 seeds in a box, too. He waters his plants every day but does not give them any plant food. Randy and Josette put the boxes where they will get the same amount of light. They make sure they give the seeds the same amount of water. Then everyone waits.



About three weeks later, Carmen says that the plants look big enough to be measured. She measures the heights of the plants with no plant food. Two of the plants in the NO PLANT FOOD group didn't come up at all; so she writes two 0s for their heights. Then she measures the heights of the plants that got plant food. One of the plants in that group didn't come up either; so she lists its height as 0, too. The data look like this.

HEIGHTS OF PLANTS WITH NO PLANT FOOD (cm)

0, 0, 3, 2, 7.5, 6, 4.5, 5.5, 6, 5, 6.5, 7, 8, 2.5, 4

HEIGHTS OF PLANTS WITH PLANT FOOD (cm)

0, 0.5, 6, 8, 4, 7, 3, 10, 11, 6, 8, 5.5, 7.5, 5, 3

Josette knows what to do next. She puts the data in order from smallest to largest.

NO PLANT FOOD (cm): 0, 0, 2, 2.5, 3, 4, 4.5, 5, 5.5, 6, 6, 6.5, 7, 7.5, 8

PLANT FOOD (cm): 0, 0.5, 3, 3, 4, 5, 5.5, 6, 6, 7, 7.5, 8, 8, 10, 11

Then she finds the median for each set of data.

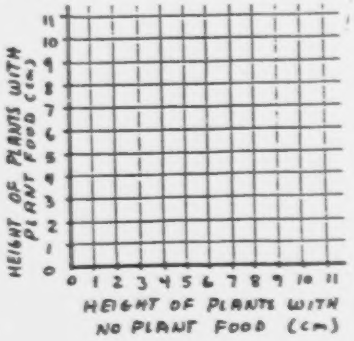
NO PLANT FOOD (cm): ~~0~~, ~~0~~, ~~2~~, ~~2.5~~, ~~3~~, ~~4~~, ~~4.5~~, 5, ~~5.5~~, ~~6~~, ~~6~~, ~~6.5~~, ~~7~~, ~~7.5~~, ~~8~~
median

PLANT FOOD (cm): ~~0~~, ~~0.5~~, ~~3~~, ~~3~~, ~~4~~, ~~5~~, ~~5.5~~, 6, ~~6~~, ~~7~~, ~~7.5~~, ~~8~~, ~~8~~, ~~10~~, ~~11~~
median

Josette is disappointed. The median heights are close. She tells her friends, "It looks like the plants do just as well with no plant food as they do with plant food."

Randy smiles. "While we were waiting for the plants to get big enough to measure, I asked the teacher how to compare our data. We can make a q-q graph. If there is a difference, we will be able to tell.

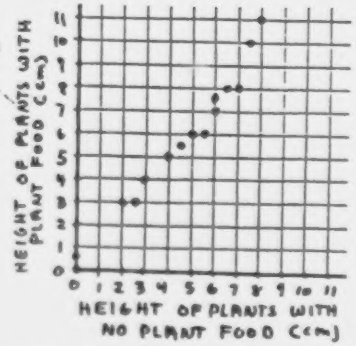
Randy draws two number lines on a piece of graph paper. He labels the horizontal axis HEIGHT OF PLANTS WITH NO PLANT FOOD, and the vertical axis HEIGHT OF PLANTS WITH PLANT FOOD. The graph looks like this.



Then Randy takes the two sets of data and lines them up next to each other so that the first numbers are matched, the second numbers are matched, and so forth. The data look like this:

NO PLANT FOOD	0	0	2	25	3	4	4.5	5	5.5	6	6	6.5	7	7.5	8
PLANT FOOD	0	0.5	3	3	4	5	5.5	6	6	7	7.5	8	8	10	11

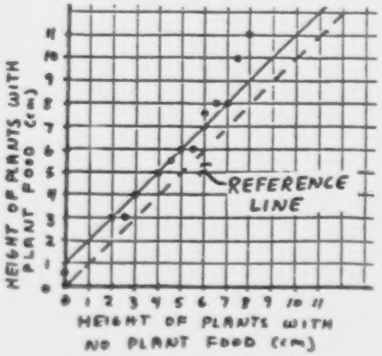
Randy plots the pairs of numbers on the graph paper. First he plots (0,0). Then he plots (0, 0.5). He plots all the pairs of points. Now the graph looks like this:



But Randy is not finished. He draws a dashed line through the points (0,0), (1,1), (2,2), (3,3), and so forth. He says, "This dashed line is called a REFERENCE LINE. It is what we would get if the two sets of data were exactly the same. We can compare our data with this line." Next he draws a solid line that goes through most of the points that show the data. The points that are not exactly on the line are close to the line. The graph looks like this.

"Well, what does it mean?" asks Josette.

Randy explains. "The solid line for the data is one space or one centimeter above the reference line. The solid line is parallel to the reference line, too. That space shows that not only are the medians one centimeter apart, but most of the plants (when we put them in ordered pairs) are one centimeter apart in height. Since the solid line is ABOVE the reference line by one centimeter, that means that most of the plants getting plant food are about one centimeter taller than the plants with no plant food. The plant food helps most of the plants the same amount."



"What if the line for the data were steeper?" asks Josette. "What would that mean?"

"It would mean that the plant food helps the bigger plants more than the smaller plants. The big plants getting plant food would be growing faster than the small plants getting plant food. It looks like that is happening anyway. The two points that are quite far above the solid line are the points for the taller plants."

Carmen looks at those points. "Maybe by the time the plants start to get big, they use up the food that is in the soil. Maybe that's when they really need the plant food. I think that we should get plant food."

Josette and Randy agree with Carmen. Josette says, "The plant food helps all the plants a little bit. It helps the bigger plants more than the smaller plants. We should buy plant food and give it to all the plants that are taller than 6 centimeters."

MAKING A SCATTER GRAPH

Sometimes you may collect two different kinds of data about the same things.

- *You might measure the heights of all of your plants and also count their leaves.*
- *You may have listed how many children in each grade have a bike and how many ride their bikes to school.*

You may want to find out if your two sets of data are ***related****.*

- *You may wonder whether a tall plant has more leaves than a short plant.*
- *You may guess that grades where more children have a bike are the grades where more children ride their bikes to school.*

But you aren't sure. How can you find out? You can make a SCATTER GRAPH of your data to find out. The SCATTER GRAPH WILL SHOW YOU WHETHER THE DATA ARE RELATED. The SCATTER GRAPH will show you whether your guess is right.

In this story, the children want to find out whether the foods that are thrown out the most in the lunchroom are the foods that most children don't like. They find out by making a scatter graph.

Ricky's class wants to improve the food served in the lunchroom. Ricky, Dana, Michelle, and Peggy are working in a group to find out which foods the students throw out and which foods the students dislike. They have already done a lot. They have collected data about each food served in the lunchroom in these two ways:

The First Way: Which foods are thrown out? Each day Ricky counted the number of lunches bought that day. Dana, Michelle, and Peggy took turns counting the number of portions of different foods thrown out. Since different numbers of lunches were bought each day, Ricky and Dana divided the number of portions of each different food wasted by the total number of lunches bought for that day. Then they multiplied their answers by 100% to get the percentage of each kind of food wasted that day.

Their calculations for one day look like this.

$$\frac{\text{NUMBER OF PORTIONS WASTED}}{\text{TOTAL NUMBER OF LUNCHES}} = \text{FRACTIONAL AMOUNT OF FOOD WASTED} \quad \text{and} \quad \text{FRACTION OF FOOD WASTED} \times 100\% = \text{\% OF FOOD WASTED}$$

$$\frac{\text{Spaghetti Wasted}}{\text{Number of Lunches}} = \frac{93}{310} = .30 \quad \text{and} \quad .30 \times 100\% = 30\%$$

$$\frac{\text{Salad Wasted}}{\text{Number of Lunches}} = \frac{81}{310} = .26 \quad \text{and} \quad .26 \times 100\% = 26\%$$

$$\frac{\text{Ice Cream Wasted}}{\text{Number of Lunches}} = \frac{22}{310} = .07 \quad \text{and} \quad .07 \times 100\% = 7\%$$

Then they put their data in a table. Their data for two weeks look like this.

FOOD	PERCENTAGE WASTED (%)	FOOD	PERCENTAGE WASTED (%)
Pizza	12	Salad	26
Fish	38	Boiled Potatoes	60
Chicken	17	Lima Beans	77
Meatloaf	47	String Beans	37
Spaghetti	30	Beets	68
Tuna Casserole	72	Baked Beans	48
Hot Dogs	12	Corn	27
Stew	76	Jello	22
Hamburger	9	Ice Cream	7
Soup	40	Cookies	5
Peas	63	Fruit	20
French Fries	21	Cake	8
Cole Slaw	52		

The Second Way: Which foods do students dislike? Peggy and Michelle surveyed the other children in the school to find out what foods students dislike. Then they tallied the data and found a percentage, too. They found the percentage of students who said they disliked a certain food. Their data look like this.

FOOD	PERCENTAGE WHO DON'T LIKE IT (%)	FOOD	PERCENTAGE WHO DON'T LIKE IT (%)
Pizza	32	Salad	48
Fish	52	Boiled Potatoes	71
Chicken	23	Lima Beans	81
Meatloaf	43	String Beans	40
Spaghetti	38	Beets	84
Tuna Casserole	68	Baked Beans	62
Hot Dogs	17	Corn	19
Stew	82	Jello	46
Hamburger	12	Ice Cream	10
Soup	42	Cookies	4
Peas	51	Fruit	52
French Fries	25	Cake	11
Cole Slaw	60		

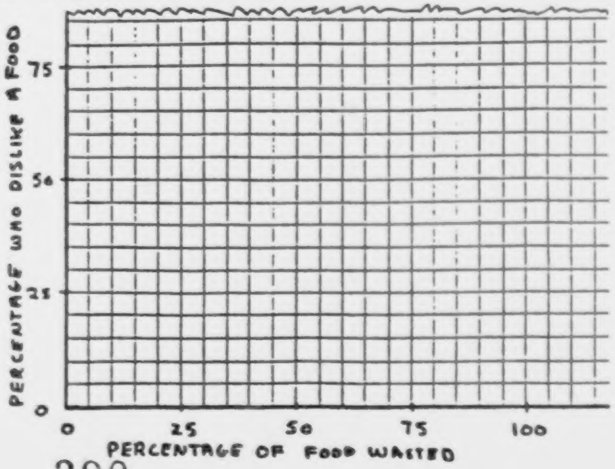
Now the group wants to compare the two sets of data to find out whether the foods that are thrown out are the same as the foods that are disliked. They want to compare two things about each kind of food: how much is wasted and how many children say they don't like it. They want to look at both of these things at the same time. They need to make a graph.

The group talks about what kind of graph they should make. They know that they have two kinds of data about the same things; so they decide to make a scatter graph. First they make a combined data chart. It looks like this.

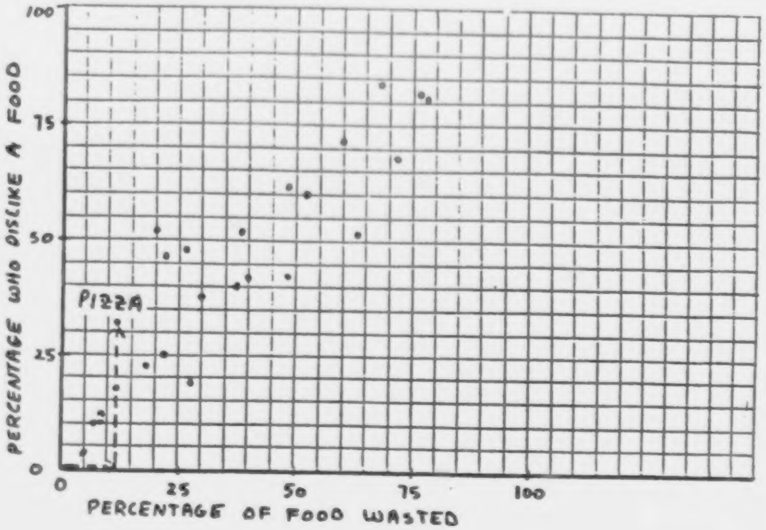
FOOD	PERCENTAGE WASTED (%)	PERCENTAGE WHO DON'T LIKE IT (%)
Pizza	12	32
Fish	38	52
Chicken	17	23
Meatloaf	47	43
Spaghetti	30	38
Tuna Casserole	72	68
Hot Dogs	12	17
Stew	76	82
Hamburger	9	12
Soup	40	42
Peas	63	51
French Fries	21	25
Cole Slaw	52	60

FOOD	PERCENTAGE WASTED (%)	PERCENTAGE WHO DON'T LIKE IT (%)
Salad	26	48
Boiled Potatoes	60	71
Lima Beans	77	81
String Beans	37	40
Beets	68	84
Baked Beans	48	62
Corn	27	19
Jello	22	46
Ice Cream	7	10
Cookies	5	4
Fruit	20	52
Cake	8	11

Then they get some graph paper. They draw two number lines on the graph paper. They label the horizontal line PERCENTAGE OF FOOD WASTED and the vertical line PERCENTAGE WHO DISLIKE A FOOD. Then they put on the scales. They know that percentage goes from 0% to 100%, so they number each line by 25s up to 100%. The graph looks like this.



Now they must put the points on the graph. For each food, they put a point on the graph that shows the percentage of that food wasted and the percentage of children who don't like that food. To put the point for pizza on the graph, they count over 12 to the right and then count up to 32. They put all of the points on the graph this way. When they finish, the graph looks like this.



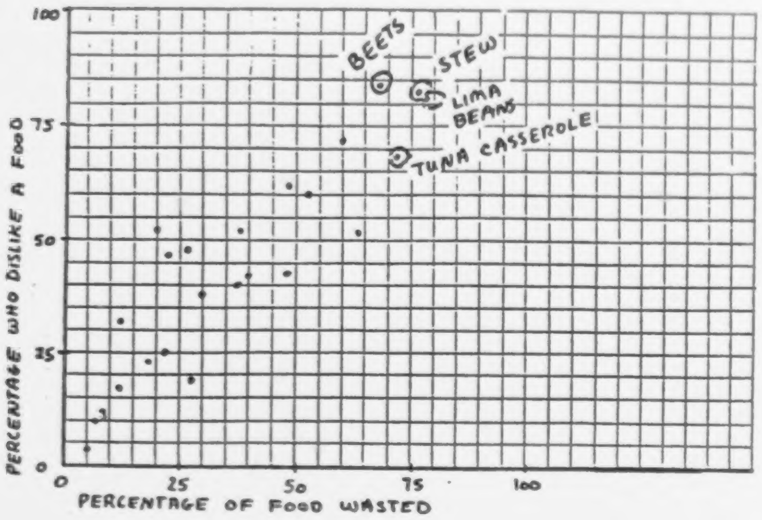
The children look at the finished graph. They notice several things. "Most of the points are going from the lower left corner of the graph up to the upper right corner. They are making a pattern," says Peggy.

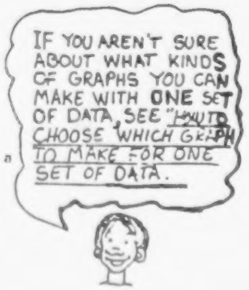
"Yes," says Michelle. "The foods that aren't thrown out much are the ones that few students say they don't like and the foods that are thrown out a lot are the ones that many students say they don't like."

Dana is interested in another thing about the graph. "I can see that each point stands for a certain food. All we have to do to find the foods that are thrown out the most and the foods that most students say they don't like is to look at the points in the upper right corner of the graph and see which foods these points stand for."

Peggy looks at the points in the top right corner of the graph. "Look," she says, "tuna casserole, stew, lima beans, and beets were the most thrown out and the most disliked. We should ask the cook to stop serving those foods." She draws circles around all those points so that the others can see them.

Now the graph looks like this. The group decides that they will take the graph to the cook and show it to her when they ask her to stop serving those foods.




IF YOU AREN'T SURE ABOUT WHAT KINDS OF GRAPHS YOU CAN MAKE WITH ONE SET OF DATA, SEE "HOW TO CHOOSE WHICH GRAPH TO MAKE FOR ONE SET OF DATA.

HOW TO PICK A GRAPH FOR YOUR DATA

Look at ONE SET of your data--it doesn't matter which one.

Can you make a BAR GRAPH from it? If so, you may want to make a LINE CHART for both sets. Your two sets of data may be

- Number of students vs. Playground Equipment Preferred for Grades 1-3 and Grades 4-6
- Number of Cars vs. Days of the Week for Morning and Afternoon
- Number of Seeds Stored vs. Days of the Week for Your Pet Hamster and Your Pet Gerbil.

Can you make a LINE GRAPH from one set of your data? If so, you may want to make a DOUBLE LINE GRAPH for both sets. Your two sets of data may be

- Average Height vs. Number of Days for Plants in Sun and Plants in Shade
- Temperature vs. Time of Day for Monday and Tuesday
- Length vs. Weight for Two Different Brands of Rubber Bands.

Can you make a HISTOGRAM from one set of your data? If so, you may want to make a DOUBLE HISTOGRAM or a Q-Q GRAPH for both sets. Your two sets of data may be

- Number of Students vs. Spelling Scores (in groups) for Before and After
- Number of Plants vs. Heights of Plants (in groups) for Plant Food and No Plant Food
- Number of Students vs. Crossing Times (in groups) for Oak Street Intersection and Main Street Intersection.

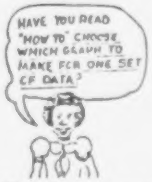
If NONE of these apply to YOUR data, look at BOTH sets of your data. Do you have two different MEASUREMENTS or NUMBER COUNTS of the same thing for a whole group of things? Then you may want to make a SCATTER GRAPH. Your two sets of data may be

- Percentage of a Food Wasted vs. Percentage of Students Disliking that Food for Many Foods
- Height of a Plant vs. Number of Leaves That Plant Has for Many Plants
- Height of a Student vs. Weight of That Student for Many Students.

If the graph that you choose doesn't tell you what you want to know, then you may need to REORGANIZE your data. That may help you to draw a different graph that will tell you what you want to know.

"HOW TO"

MAKE A HISTOGRAM

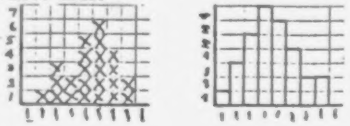

HAVE YOU READ "HOW TO" CHOOSE WHICH GRAPH TO MAKE FOR ONE SET OF DATA?

Do you have lots of measurements or number counts from many different people? Perhaps you have measured eye-level heights to find out the best heights to hang posters so that most children can see them easily. Or maybe you have counted the number of right answers each child in your class got on a test.

Do you wonder how your measurements or number counts will help you answer your questions? You can make a HISTOGRAM.

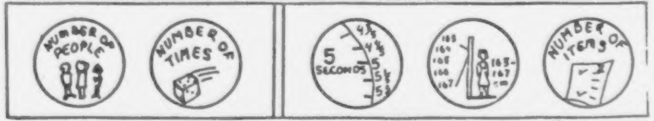
WHAT IS A HISTOGRAM?

A histogram is a kind of bar graph. It is a picture of the number of times the same measurement or number count comes up or the same thing happens. Each column in a histogram stands for a group of measurements or number counts. The height of the bar tells how many times those measurements or number counts were listed in the data chart. A histogram will help you see patterns in the measurements you have made.



WHEN SHOULD YOU MAKE A HISTOGRAM?

Make a histogram when your measurements or number counts are in groups or when it helps to put them into groups. Then your data are NUMBER COUNTS and GROUPED MEASUREMENTS or other NUMBER COUNTS.



NUMBER COUNTS AND GROUPED MEASUREMENTS OR NUMBER COUNTS

This booklet will help you decide how to make a histogram that answers the questions you have.

WHAT'S INSIDE

PAGE
HOW MANY SCORED HIGH ON THE TEST? 2
WHAT IS THE BEST HEIGHT TO HANG POSTERS? 5
HOW LONG DOES IT TAKE TO FIND THE LIBRARY? 8
HOW MANY OF EACH SIZE BELT SHOULD WE MAKE? 10
THINGS TO KEEP IN MIND ABOUT HISTOGRAMS 13

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HOW MANY SCORED HIGH ON THE TEST?

Suppose you want to know how all the students in your class scored on a test. The test has eight questions on it.

You count the number of right answers each student made. Here are the numbers for 24 students.

Number of Right Answers

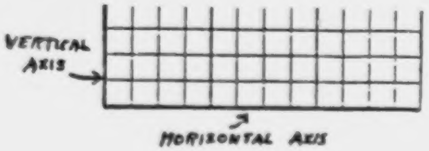
5	2	7	3
6	6	7	4
3	6	4	5
7	4	5	4
6	8	5	6
5	6	6	7

You have lots of numbers. What is an easy way to tell how many students scored high on the test and how many scored low on the test? You can count the number of students who got 0 right, 1 right, and so on. You can tally on a data chart like this.

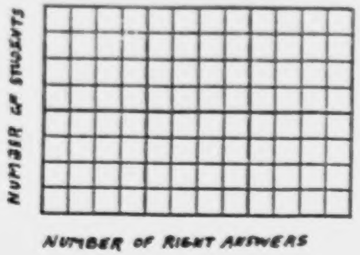
SCORES ON TEST DEC. 3

NUMBER OF RIGHT ANSWERS	NUMBER OF STUDENTS
0	
1	
2	/
3	//
4	////
5	𝍸
6	𝍸 //
7	////
8	/

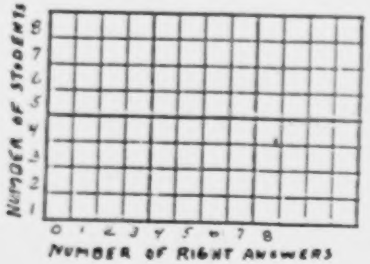
The tally sheet looks like a histogram turned sideways. You can make a real histogram. It will show the data better. Here is how to make one. First, draw two lines on graph paper. One line goes across the bottom of the paper. The other line goes along the left side of the paper. The bottom line is called the horizontal axis. The side line is called the vertical axis.



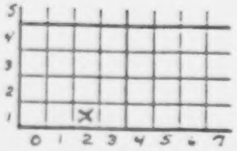
The horizontal axis is for the number of right answers. The vertical axis is for the number of students. Label the two lines. Leave room to put numbers near the lines.



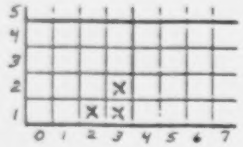
Next, write the numbers 0 to 8 in the spaces below the horizontal axis. These numbers are for the number of right answers. Write numbers from 1 to 7 in the spaces along the vertical axis. These numbers are for the number of students.



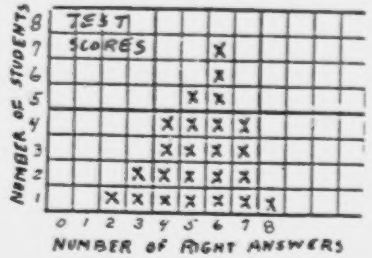
Now you are ready to put the data on the histogram. Look at your data chart. One student got 2 answers right. Put an X in the column marked 2 on the horizontal axis.



Two students got 3 answers right. Put two Xs in the column marked 3 on the horizontal axis.



Keep filling in Xs until all the data is on the histogram. You have scores from 24 students. There should be 24 Xs on the histogram. Now put a title on the graph. The finished histogram looks like this.



What does the histogram tell you? The tallest column is marked 6. More students got 6 answers right than any other number. You can also see from the pattern of Xs that most of the students got more than 4 of the 8 answers right. One student got 2 right and one student got 8 right.

WHAT IS THE BEST HEIGHT TO HANG POSTERS?

In the first example you made a histogram from data on NUMBER COUNTS and NUMBER COUNTS. Each column showed one number. In this example you make a histogram from NUMBER COUNTS and MEASUREMENTS. You put the measurements into groups before you make the histogram.

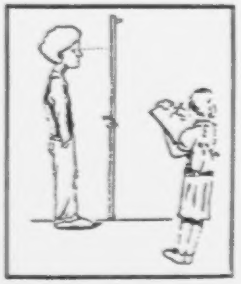
Suppose that you are making posters to advertise different things to buy and sell to students in your grade. You will hang the posters in your classroom, in the other classrooms, and in the hallway near your room. At what height should you hang the posters so that others in your grade will be able to read them easily? You want to hang the posters so that not too many students will have to look down at the posters and not too many students will have to look up at them.

HOW HIGH DO I PUT IT?

First you need to collect data. You measure the height of each student in your class. Because you will be hanging the posters at eye level, you measure each student from his or her eye level to the floor. You read "How To" Round Off Data as You Measure and decide to round off each measurement to the nearest centimeter. Here are the measurements you have made for 31 students.

EYE-LEVEL HEIGHTS (cm)

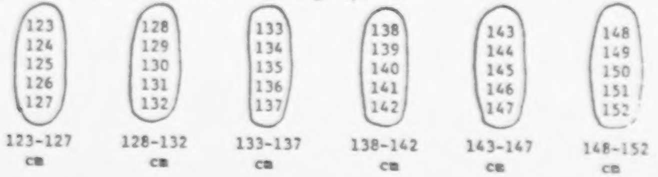
137	140	133	146	140
145	126	141	142	134
133	139	134	150	138
138	146	137	147	140
151	140	131	141	135
151	141	131	150	142
				144



You have lots of numbers. What should you do with them? It will help to put the measurements into groups and then make a histogram. That way, you can see whether there is a pattern to the measurements.

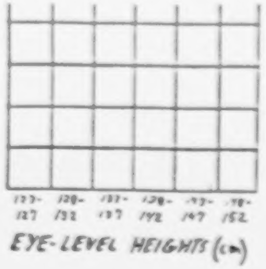
What grouping should you choose for your histogram? That depends on the question you want to answer. For this problem, you can put your measurements into groups of 5 centimeters. A difference of 5 centimeters in height is big enough to make some difference in how well someone can read a poster, but not so big that you can't see the pattern in the measurements.

Which grouping of 5 centimeters should you choose? You have to consider two things. First, the shortest height you measured is 126 centimeters. The tallest height is 151 centimeters. So you know that your groupings will have to include both 126 centimeters and 151 centimeters. Second, when possible the middle of each grouping should be a number ending in 5 or 0. These are common numbers which can be used to tell about the whole grouping. The two things are taken care of with groups of:

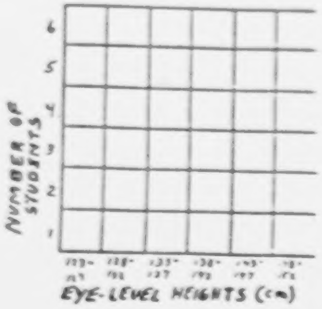


Notice that the groupings are equal; each has 5 measurements in it. The groupings are arranged in order from smallest to largest. The middle of each grouping is a number ending in 5 or 0.

Now that you have made your groupings, draw two lines on graph paper. The horizontal axis will be for the different groupings of heights you measured in centimeters. Label that line EYE-LEVEL HEIGHTS (cm). These are the measurements you put into groups of 5 centimeters. Write the numbers in the spaces along the bottom line.



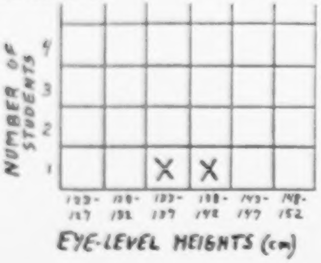
The vertical axis is for the number counts. Label that line NUMBER OF STUDENTS. You can use either Xs or bars in a histogram. (Usually, we use Xs when we can count by ones. We use bars when we count by more than one.) In this booklet we will use Xs. Write numbers beginning with 1 in the spaces beside the vertical axis.



Now the graph is ready to be filled in. You can tally your data right on the histogram. The first number is 137. Put an X in the column 133-137. The next number is 140. Put an X in the column 138-142.

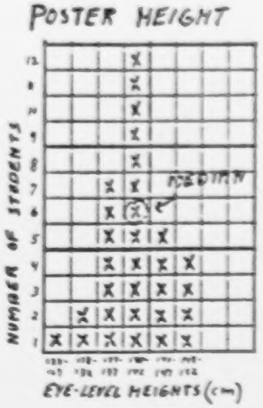
EYE-LEVEL HEIGHTS (cm)

137	140	133	146	140
145	126	141	142	134
133	139	134	150	138
138	146	137	147	140
151	140	131	141	135
151	141	131	150	142
				144



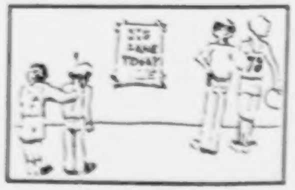
Keep filling in Xs until you have shown all the data. Each X stands for one student. You measured 31 students; so you should have 31 Xs. Check your graph to make sure that you do. Finally, put a title on your graph.

The finished graph looks like this. What does it tell you? You can see that more of the heights fall in the middle grouping than in any other grouping. The other heights are pretty evenly divided on either side of the column.



To make sure that the heights are evenly divided on either side of the middle grouping, you can find the median height. That is the number that falls exactly in the middle of the data. (If you need help, read the booklet "How To" Find the Median.) The median measurement is in the 138 cm to 142 cm grouping. You can think about the middle group as being about 140 centimeters, because 140 is right in the middle of 138 and 142.

Now you know that you can hang each poster so that its center is 140 centimeters from the floor. That height will be good for most people you measured. The posters may be a bit too high for some students and a bit too low for others. But 140 centimeters is probably as fair a height as you can find for all the students in your grade.



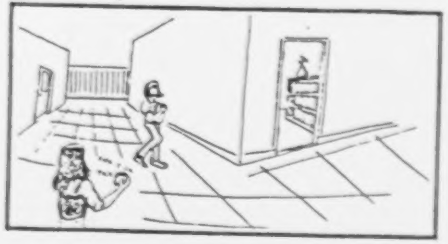
HOW LONG DOES IT TAKE TO GET TO THE LIBRARY?

In the last example you used a histogram to find the median height. You can also use a histogram to find out what measurements or number counts most people had. You might want to find out what scores on a test most children had as in the first story in this booklet. Or maybe you want to find out the time it took most children to find a certain place in the school. That is what this example is about.

WHERE IS THE LIBRARY?

Suppose that many younger children in your school get confused trying to find the school library. Your class wants to make signs to help them find their way. But before you do, you would like to see how long it takes some first graders to find the library on their own.

Let's say that there are 8 first grade classes. It would be too much work to time all the children; so you pick a sample of 25 students. (If you don't know how to pick a sample, read the booklet "How To" Choose a Sample.) Then you make a starting point in the hallway near the first grade classrooms. With a stopwatch, you time each child as he or she tries to find the library from the starting point.

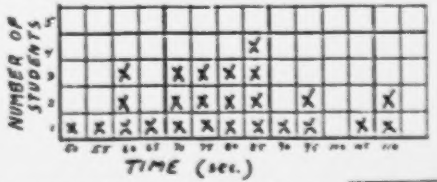


You decide to round off the measurements to the nearest five seconds because that is about as accurate as your measurement can be. Here is a list of the times.

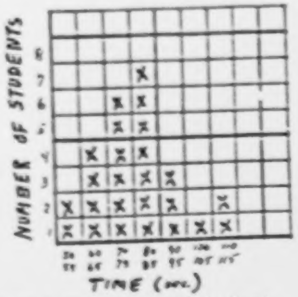
NUMBER OF SECONDS TO FIND THE LIBRARY
(rounded off to nearest 5 seconds)

60, 75, 80, 100, 50, 95, 70, 75, 110, 60, 55, 75, 80, 85
65, 110, 95, 85, 85, 60, 70, 70, 85, 80, 90

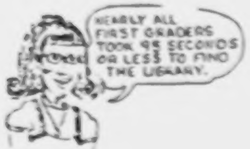
Now how should you group your measurements? That depends on your purpose for making the histogram. You want to find out the time it takes most children to find the library before you hang signs. You will then want to compare those data with the time it takes most children to find the library after the signs are up. So you want to have fairly small groups. You might decide to have each group include times within 5 seconds of one another. Your data are already in 5-second groups because of the way you rounded off. You first make a histogram with each rounded-off measurement in one column. Your histogram looks like this.

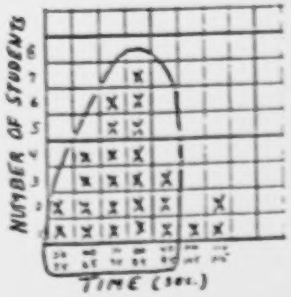


You decide that the graph looks too flat. It is hard to see a clear pattern. You decide to put two measurements in each column. Your next histogram looks like this.



This histogram lets you see the pattern of numbers in a way that would be hard to see from your list. You can follow the top X of each column to the side number. That will tell you how many children there were in each time period. You can see, for example, that 7 students took 80 or 85 seconds to find the library. You can tell from the graph that nearly all the children, 22 out of 25, took 95 seconds or less to find the library.


NEARLY ALL FIRST GRADERS TOOK 95 SECONDS OR LESS TO FIND THE LIBRARY.



HOW MANY OF EACH SIZE BELT SHOULD WE MAKE?

When you are making things to fit a lot of people, you will probably need to figure out ahead of time what sizes are needed and how many of each size to make. This may happen if you are making aprons for the Design Lab, or tables for your classroom, or belts or slippers to sell at a school fair.

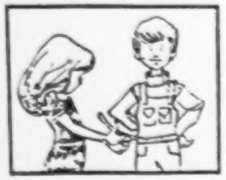
A histogram can help you see the pattern of measurements you have made. This example shows you how to use a histogram to answer your questions about sizes.

Your class may want to make belts to sell to other students in the school. How do you decide what the sizes should be? And how many different sizes should you make?

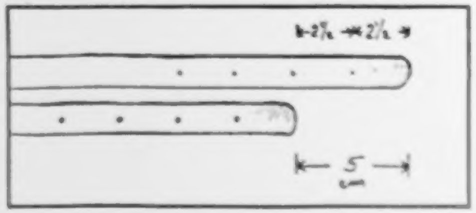
First, you choose a sample of 30 children in the school. You measure their waists and round off the measurements to the nearest centimeter. Here is a list of the data you collected.

WAIST SIZES (nearest centimeter)

66, 61, 65, 63, 65, 62, 71, 70, 67, 65, 74, 70
65, 75, 68, 61, 71, 65, 66, 60, 66, 71, 70, 64
76, 72, 70, 66, 72, 60



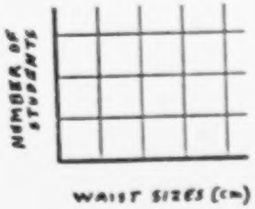
You don't want to make a special belt size for each child. You decide to put your data into groups. But how big should the groups be? To find out you measure the distance between two holes in the belt. You find that the distance is about 2½ centimeters. You decide to put four holes in each belt. You also decide to have two holes in one size overlap two holes in the next size. Then you figure that the difference in lengths will be 5 centimeters.



You decide to put your data into 5-centimeter groups. That means that you will have sizes for children whose waists are about 60 centimeters, 65 centimeters, 70 centimeters, and so on.

You still need to decide how many sizes to make and about how many belts to make in each size. You need to see the pattern of the measurements; so you will make a histogram.

Set up the graph as usual, with the horizontal axis for the grouped measurements (waist sizes) and the vertical axis for the number counts. Be sure to label the lines.

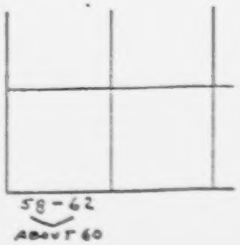


You have already decided to put the measurements into groupings of 5 centimeters, but which number should you start with? You can see from the list that the smallest waist size is 60 centimeters and the largest is 77 centimeters. Your groupings will have to include both 60 centimeters and 77 centimeters.

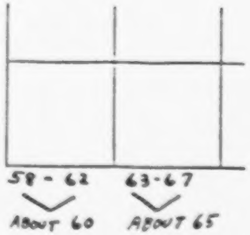
THE SMALLEST WAIST IS 60 CM.

THE LARGEST WAIST IS 77 CM.

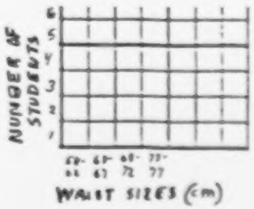
Make the first grouping 58-62 centimeters. It will take care of five measurements: 58, 59, 60, 61, and 62 centimeters. The middle number is 60. This grouping will be for the children whose waists are about 60 cm.



Then the next grouping will go from 63 to 67 centimeters. That will take care of the children whose waists are about 65 cm.



Keep doing this until you have all the groupings of 5 that you need. Fill in the side numbers. Then you are ready to draw the histogram.

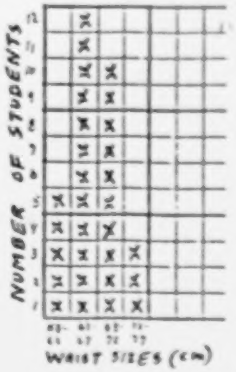


For each measurement in your list of data, make an X in the correct column. The finished histogram looks like this:

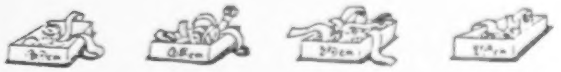
WAIST SIZES (cm)

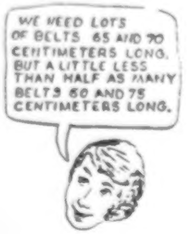
66, 61, 65, 63, 65, 62, 71, 70, 67, 65, 74,
70, 65, 75, 68, 61, 71, 65, 66, 60, 66, 71,
70, 64, 76, 72, 70, 66, 72, 60

There are four columns. That means that you should make at least four sizes of belts. Your groupings included waist sizes of a sample of students. A few students not in the sample might have waist sizes smaller or larger than those measured. For these students you might make belts to order rather than have very small or very large belts on hand.



The two middle columns in the histogram are the highest. That means that you should make lots of belts to fit people whose waists are about 65 centimeters and about 70 centimeters. The columns on the ends are much shorter. You don't need to make as many belts in those sizes.




WE NEED LOTS OF BELTS 65 AND 70 CENTIMETERS LONG. BUT A LITTLE LESS THAN HALF AS MANY BELTS 60 AND 75 CENTIMETERS LONG.

THINGS TO KEEP IN MIND ABOUT HISTOGRAMS

IS A HISTOGRAM THE BEST GRAPH TO SHOW YOUR DATA AND ANSWER YOUR QUESTIONS?

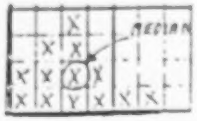
- Is one part of your data NUMBER COUNTS?
- Is the other part of your data NUMBER COUNTS or MEASUREMENTS?
- Do you have 15 or more measurements?

If your answer to all three questions is "yes," a histogram is probably a good graph to make.

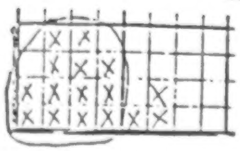
If you answered "no" to any question, you might want to make another kind of graph. The booklets "How To" Choose Which Graph to Make for One Set of Data and "How To" Use Graphs to Compare Two Sets of Data might help you find a better graph for your data.

WHAT KINDS OF QUESTIONS CAN A HISTOGRAM HELP YOU ANSWER?

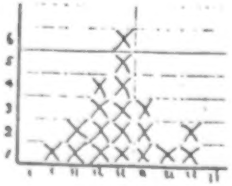
- What is the best height to put posters, chalkboards, or a pencil sharpener?



- How many seconds does it take most first-graders to find the library? Most children to cross the street?

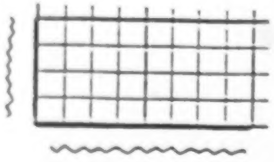


- How many of each size belts, or caps or wristbands should we make? How many of each size swings or monkey bars should we buy?

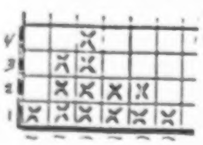


THINGS TO REMEMBER WHEN YOU DRAW YOUR HISTOGRAM

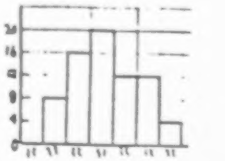
1. Draw the axes carefully. Follow the lines of the graph paper. Write what each of the axes stands for.



2. The vertical axes is for the number counts. A histogram can have either Xs or bars. If your graph will have Xs, write the numbers beside the spaces.



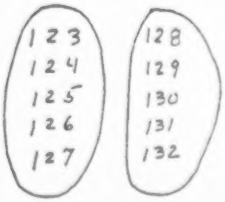
If you don't have enough spaces on the side line for all your Xs, you can make each space stand for more than one number. Then you can make bars instead of Xs. When you have bars, write the number beside the lines.



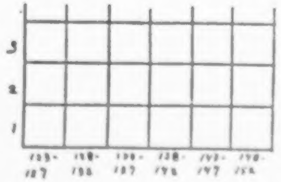
3. The horizontal axis is for your grouped measurements or number counts.

Decide how big yrur grouping should be. Does the question you are asking tell you how big the groups should be?

Decide where each group should begin and end. If they are large groups try to have a number ending in 5 or 0 in the middle of each group. Make sure there is a place to tally every piece of data from the smallest to largest.


123
124
125
126
127
128
129
130
131
132

Write the groups in order from smallest to largest under the spaces.



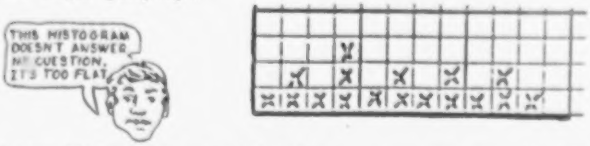
4. Put your data on the graph.

5. Make up a title for your graph so that others will understand what it shows.

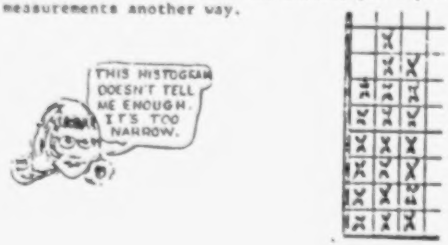
THINGS TO THINK ABOUT AFTER YOU HAVE MADE YOUR HISTOGRAM

- Figure out what the graph tells you. Were your questions answered? Can others read the data on the graph easily? What patterns do you see?

- Is there a better way to show your data? If your histogram is too flat and wide, you may want to collect more data or make larger groupings.


THIS HISTOGRAM DOESN'T ANSWER MY QUESTION. IT'S TOO FLAT.

If your histogram is too tall and narrow, you may want to group your measurements another way.


THIS HISTOGRAM DOESN'T TELL ME ENOUGH. IT'S TOO NARROW.

408

"HOW TO"

MAKE A LINE GRAPH

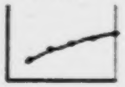
DO YOU WANT TO COMPARE A SERIES OF MEASUREMENTS COLLECTED FOR DIFFERENT TIMES, WEIGHTS, OR DISTANCES?

You may want to keep track of how the temperature changes during the day. You may want to find out how your plant grows over a period of several weeks. You may want to find out how fast a model car rolls when it starts at different heights on a hill. You may want to find out how much an elastic stretches for different weights.

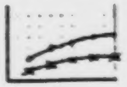
If you want to know how several measurements compare with one another, you can make a LINE GRAPH.

WHAT IS A LINE GRAPH?

A line graph is a picture of a series of measurements. It can tell you how something is growing or how it is changing. A line graph is special because it helps you find extra information that you didn't know about when you started.

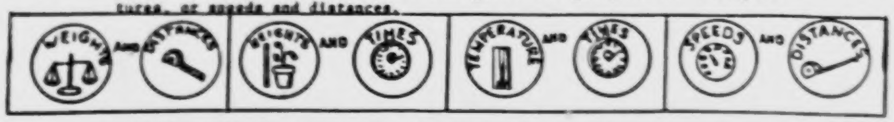


Making two line graphs can help you compare two sets of data so that you can get even more information.



WHEN SHOULD YOU MAKE A LINE GRAPH?

You can make a line graph when both parts of your data are measurements. The measurements might be times and weights or heights, times and temperatures, or speeds and distances.



This booklet will show you how to make line graphs that will answer the questions you have.

WHAT'S INSIDE

PAGE
WATCHING A PLANT GROW 2
WHEN WAS IT HOTTEST? 5
COMPARING THE GROWTH OF TWO PLANTS 7
TESTING THE SPEED OF A MODEL CAR 10
DEFINITIONS 13
THINGS TO KEEP IN MIND ABOUT LINE GRAPHS 15

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WATCHING A PLANT GROW

Suppose that students in your class are planning to grow plants to sell at a school fair. You will grow the plants from seeds. Then, when the plants are 8 centimeters tall, you will put them into larger pots and sell them. You wonder how long before the fair you should plant the seeds so that they will be ready for repotting at the right time.

Let's say that you plant a seed on Thursday. When you come back to school on Monday, you check the pot. It looks the same as it did on Thursday and Friday. You check again on Tuesday. Nothing seems to have happened. On Wednesday, the sixth day since you planted the seed, you see a tiny green stem and the beginnings of two leaves. Your plant has sprouted. It is two centimeters high.

You set up a data chart. The day you planted the seed can be called Day 0. Because the seed didn't come up right away, the plant's height was 0 centimeters. It stayed 0 centimeters for Days 1, 2, 3, 4, and 5. On the morning of Day 6, the plant was 2 centimeters high. The first six lines on the chart are not very interesting, but the last line has given you some hope.

MY PLANT'S GROWTH	April 7
Days Since Planting	Height (cm)
0 (Thursday)	0
1 (Friday)	0
2 (Saturday)	-
3 (Sunday)	-
4 (Monday	0
5 (Tuesday)	0
6 (Wednesday)	2

MONDAY
I DIDN'T CHECK THE POT ON SATURDAY AND SUNDAY BUT I KNOW NOTHING CAME UP

The plant keeps growing. You continue to check the height at the same time each day, measuring to the nearest half centimeter.

Here is the bottom part of the data chart.

6 (Wednesday)	2
7 (Thursday)	2.5
8 (Friday)	3
9 (Saturday)	-
10 (Sunday)	-
11 (Monday)	4
12 (Tuesday)	4.5
13 (Wednesday)	4.5
14 (Thursday)	6
15 (Friday)	7

By Friday, the 15th day, the plant is 7 centimeters tall. "The plant seems to be growing fast," you think to yourself. "In another couple of days it will be ready for repotting."

You measure the plant the first thing Monday morning. It is 9.5 centimeters high. "My plant shot up 2.5 centimeters over the weekend," you say. "I had better pot it right away, since it's already taller than 8 centimeters."

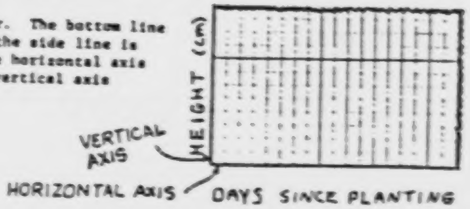
As you repot it, you wonder on which day of the weekend the plant was really 8 centimeters tall.

Days Since Planting	Height (cm)
14 (Thursday)	6
15 (Friday)	7
16 (Saturday)	?
17 (Sunday)	?
18 (Monday)	9.5

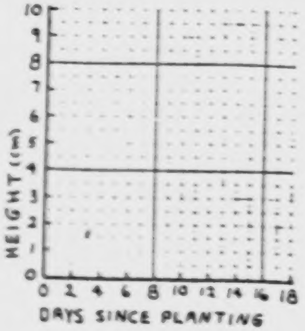
WHEN WAS THE PLANT 8 CENTIMETERS TALL?

You can make a graph to find out. Both parts of your data are measurements. One measurement is time: the number of days since the seed was planted. The other measurement is height: the number of centimeters tall your plant is. So you know that you can make a LINE GRAPH. Here is how to do it for your data.

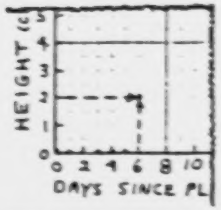
Draw two lines on graph paper. The bottom line is the HORIZONTAL AXIS, and the side line is the VERTICAL AXIS. Label the horizontal axis DAYS SINCE PLANTING and the vertical axis HEIGHT (cm).



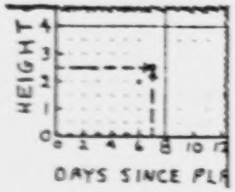
Write numbers for the days and for the height. In a line graph, you should write the numbers beside the lines of the graph, not in the spaces. The tick marks will show which lines the numbers are for.



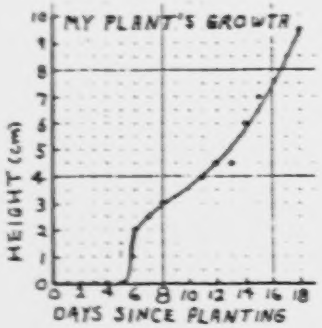
Now you can start marking the points on the graph. The data for the first six days are nearly the same. On Days 0, 1, 2, 3, 4, and 5 the seed didn't come up at all. The height of the plant was 0. Draw dots at the 0 marks for those days. On Day 6, the height was 2 centimeters. To mark that point, go over to Day 6 and up to the 2-centimeter marking. Make a large dot at the point where those lines meet.



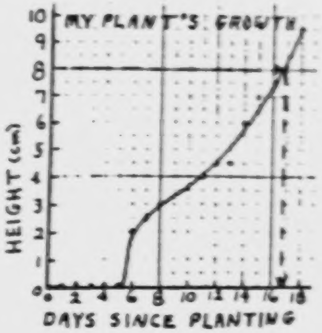
On Day 7, the plant was 2.5 centimeters tall. Go over to Day 7 and up to 2.5 centimeters. Draw a dot halfway between the marking for 2 centimeters and 3 centimeters.



Then fill in the rest of the points. When you finish plotting the points, draw a smooth line that goes through all or most of the points. The line doesn't have to go through every point because there are always errors in measurement. Also, the line shouldn't have any sharp bends in it. Here is how the graph looks for all the days up to Day 18.



The line you drew is a picture of the growth of your plant. It should tell you when the plant grew quickly and when it didn't grow at all. But how can you tell on which day the plant was 8 centimeters tall?



Find 8 centimeters on the HEIGHT line. Then run your finger along that line until you hit the line of the graph. From there, run your finger down to the DAYS SINCE PLANTING line. You have ended up between Days 16 and 17. That means that your plant probably reached 8 centimeters late on the 16th day after you planted the seed. The 16th day was Saturday.

THIS KIND OF PLANT TAKES ABOUT 16 DAYS TO REACH A HEIGHT OF 8cm

You have just figured out a piece of data you haven't measured by looking between the points of the data that you have measured. This is called interpolation. In this example, you didn't know on which day your plant was 8 centimeters tall. But you could find out by looking at the line graph you plotted. Points on the graph showed when the plant was 7 centimeters tall and when it was 9.5 centimeters tall. Then you used the line on the graph to find out possible measurements between those points.

WHEN WAS IT HOTTEST?

The last example showed you how to use a line graph to interpolate a possible measurement smaller than the largest measurement. This example shows you how to interpolate data to find the largest measurement.

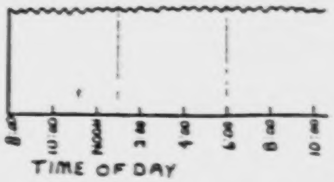
Suppose that your part of the country is having a heat wave. It has been hot for many days in a row and some weather records have been broken. One day, you decide to keep track of the temperature every two hours, starting at 8:00 in the morning and ending at 10:00 at night.

At the end of the day your data chart looks like this:

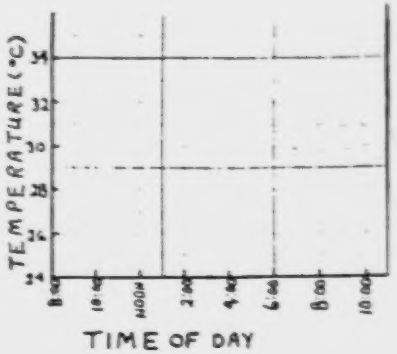
TODAY'S TEMPERATURE July 31	
Time	Temperature (Degrees Celsius)
8:00 A.M.	26
10:00 A.M.	29
Noon	32
2:00 P.M.	34
4:00 P.M.	34
6:00 P.M.	33
8:00 P.M.	30
10:00 P.M.	29

You decide to make a line graph to show how the temperature changed throughout the day. You want to see if you can find anything interesting about the times for which you have no data.

First, you set up the graph by drawing a pair of axes on graph paper. The horizontal axis is for the time. Label it TIME OF DAY and write the times under the lines. Notice that the numbers are spaced evenly along the horizontal axis.



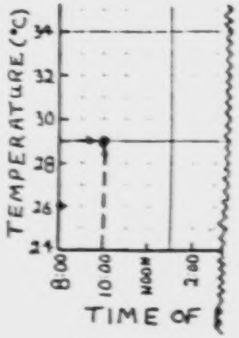
The vertical axis is for the temperatures. Label it and fill in the numbers opposite the tick marks. Because the temperatures on your data chart are 26 degrees Celsius or higher, you don't have to start with 0 degrees on your graph. In this example we begin with 24 degrees.



Now you are ready to plot the points. At 8:00 A.M. it was 26 degrees. Find 8:00 A.M. on the TIME line and then go up to 26 degrees. Make a large dot where those lines meet.

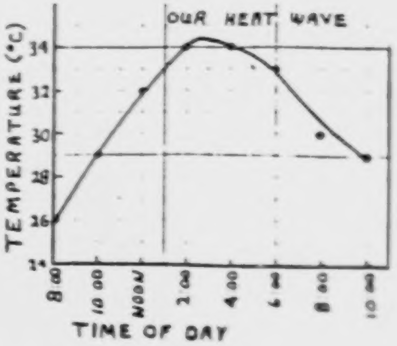
Then plot the next point: Go over to 10:00 A.M. and up to 29 degrees.

Keep plotting points. When you have plotted all the points, draw a smooth line that goes through all or nearly all of the points.



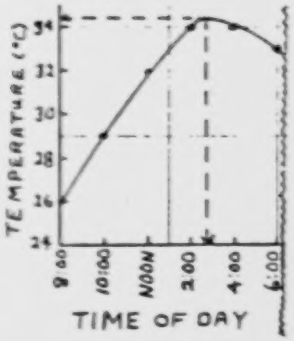
The finished graph looks like this. To draw a line with no sharp bends in it, you had to go above 34°C between 2:00 P.M. and 4:00 P.M. You went above 34°C just enough to make the line smooth.

You can see that as the day went on, the temperature got higher. Then it reached a peak just above 34°C and began to fall. You can also tell that it was as hot at 10:00 at night as it was at 10:00 in the morning.



"At what time was the temperature highest?" you might wonder. You can interpolate from the graph to figure that out. Find the peak of the curve. Run your finger down in a straight line to the TIME OF DAY line. You end up at a point that is about halfway between 2:00 P.M. and 4:00 P.M. So you can say that the temperature was probably highest around 3:00 P.M. that day.

Making a line graph helped you find out information that you didn't have on the data chart. The reason that you can interpolate is that the spaces between the lines in your measurements make sense.



COMPARING THE GROWTH OF TWO PLANTS

So far, you have learned how to make one line graph to find out how one thing is growing or changing. But you can also make two line graphs to compare the growth or change of two things. For example, you can make two line graphs to show the temperature on two days or to show the average daily temperature for two different months. You can use line graphs to compare the weights of two animals. This example shows how you can compare the growth rates of two of the same kind of plant.

Suppose that you and a friend have decided to grow avocado plants. You want to see whether the two plants will grow the same. You will each put a large avocado pit into water. Then you will wait for them to split and grow some roots. As soon as that happens, you will put the pit into a pot of soil and watch your plants grow. You know that the two avocado pits will probably not be ready for potting at exactly the same time, even if they were put into water the same day. So you and your friend agree to pot each avocado pit whenever it is ready. Then each of you will keep track of your plant's height from the day it was put into soil.

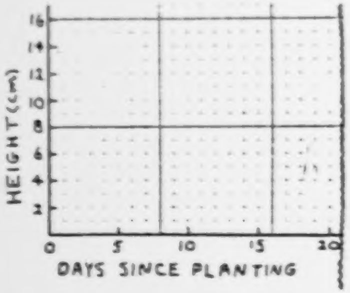
Let's say that your pit was planted on January 7 and your friend's pit was planted on January 18. You agree to measure the heights every 5 days. Each of you makes a data chart.

JIM'S AVOCADO	Jan. 7
Days Since Planted in Soil	Height (cm)
0	0
5	2
10	5
15	9.5
20	12
25	13
30	14
35	14.5

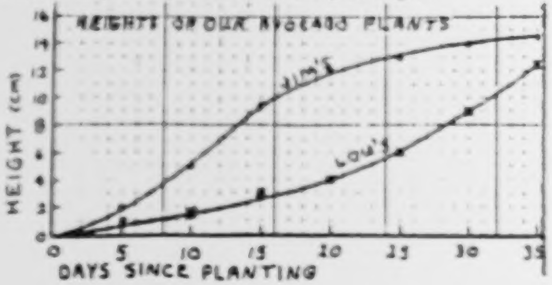
LOU'S AVOCADO	Jan. 18
Days Since Planted in Soil	Height (cm)
0	0
5	1
10	1.5
15	3
20	4
25	6
30	9
35	12.5

You can see from the data charts that on the 35th day, one avocado is 14.5 centimeters tall and the other is 12.5 centimeters tall. That is a difference of 2 centimeters. But you would like to compare how fast each of the plants grew. You will make two line graphs to compare their rates of growth.

Set up the graph. Label the horizontal axis DAYS SINCE PLANTING and write the numbers along the lines. Label the vertical axis HEIGHT (cm) and write the numbers for the height. Since the plants started at a height of 0, you should begin with 0 centimeters on the vertical line.



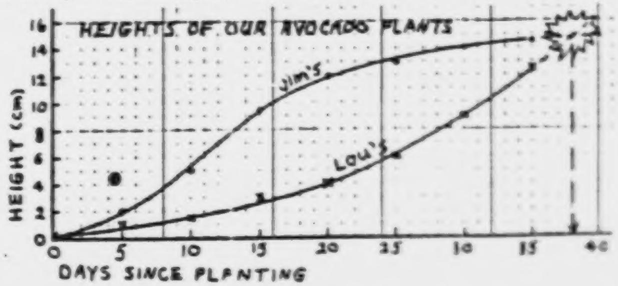
Using the data chart for Jim's avocado, you plot the points. You connect the points with a smooth line. Then you plot the points for Lou's plant and connect those points with a smooth line also. The two finished graphs look like this. What do they tell you about how the plants grew?



You can tell at a glance that the curve for Jim's plant is higher than the curve for Lou's plant. That means that on any given day after planting, Jim's plant was taller than Lou's. You can also see that the two graphs share only one point in common. On Day 0, when each plant was first put into the soil, both heights were 0. (The point where the horizontal and the vertical line meet is called the origin. So the two graphs start out at the origin, but they don't meet again.) Any time after Day 0, the plants were never the same height.

Look at the graph for Jim's plant. It rises steeply for the first 20 days and then it levels off. That means that the plant grew pretty quickly at first, and then slowed down. You could predict that after Day 35 the curve will probably get a bit higher, but it will not shoot up as quickly as it did before. You can say that the plant's rate of growth has slowed down and will probably level off at some time.

Now look at the graph for Lou's plant. It starts off much more slowly. The curve isn't as steep as it is for Jim's plant. That means that Lou's plant grew more slowly. But notice that at about Day 20, the curve gets steeper. Even at Day 35 it still seems to be rising. Lou's plant has grown quickly from Day 20 to Day 35. You could predict that Lou's plant will continue to grow quickly. In fact, Lou's plant might be as tall as Jim's plant in about three more days. Then the graphs might look like this:



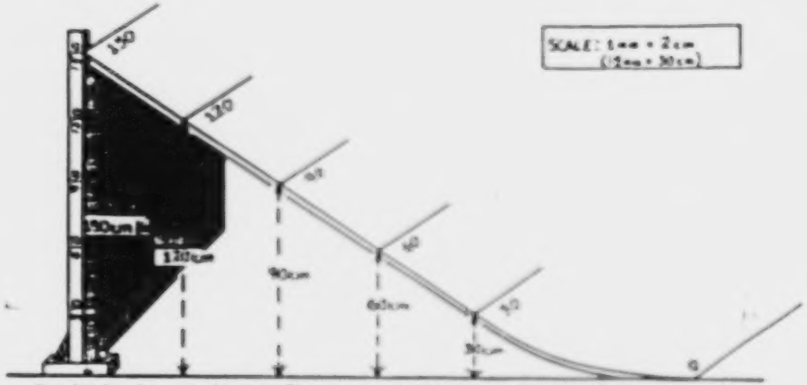
There is no way to tell for sure, but you can make a pretty good guess about what will happen to each of the plants, just by looking at the graphs of how they have grown.

When you look at the line graph to predict other measurements beyond those that you know, you are using extrapolation. When you extrapolate, you make a guess about where the next points might be. You base your guess on what you know about the graph so far. You must be careful when you extrapolate because the direction of the line might change and make your guess wrong. When you extrapolate, you should have a large number of points already on your graph. You should never extrapolate from just four or five points.

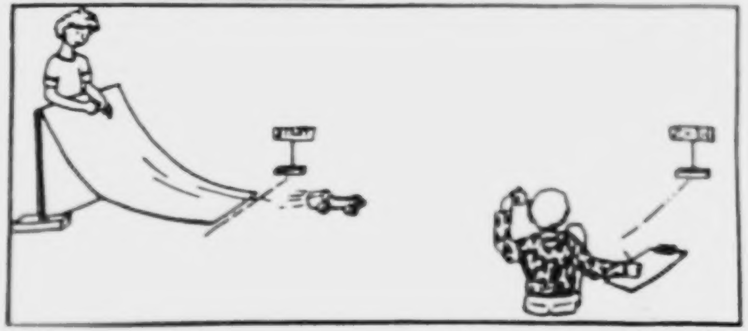
TESTING THE SPEED OF A MODEL CAR

Suppose that you and some friends have become interested in how fast model cars travel across a level floor when they start off on a hill. One person thinks that how fast a car rolls depends on how high on a hill it starts off. Others are not so sure, so you decide to do an experiment.

You make a wooden ramp like the one shown below. You fix it so that the top is 150 centimeters from the floor. Then you make equal markings on the ramp to show the height from the floor every 30 centimeters. You make a START line on the level floor at the bottom of the hill. You mark a STOP line 5 meters from the START line.



You begin the experiment. First you put the car at the top of the ramp and let go. The car rolls down the ramp and across the floor. When the front of the car crosses the START line, you start a stopwatch. When the front of the car crosses the STOP line, you stop the stopwatch and read the time. Then you compute the speed of the car. (If you need help in doing this, read the booklet "How To" Find the Speed of Things.)

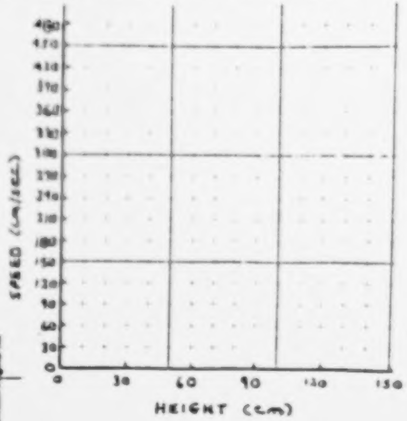


Each time you start the car at a different height on the ramp. Each time you figure out the speed. Here is what you have found.

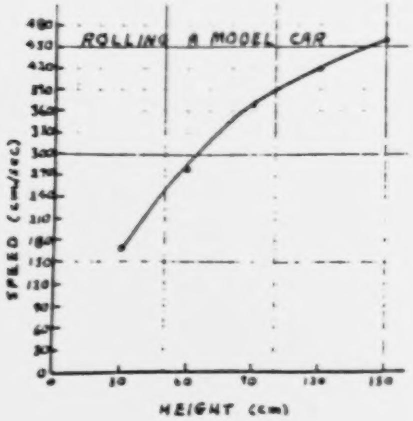
ROLLING A MODEL CAR	Nov. 20
Height Started (cm)	Speed of Car (cm per sec.)
150	460
120	420
90	380
60	270
30	170

You would like to see how the speed changes, so you decide to make a line graph.

Set up the graph by drawing a pair of axes. Put the height along the horizontal axis and the speeds along the vertical axis. Label each axis and fill in the numbers. Notice that each space along the bottom axis stands for 10 centimeters. Each space along the side axis stands for a speed of 30 centimeters per second.

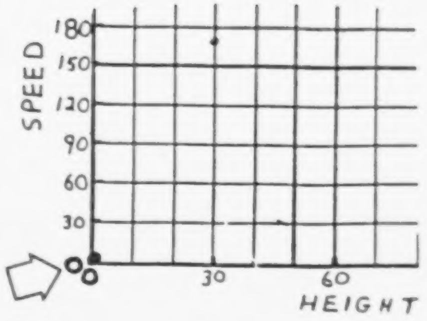


Then, using the data chart, plot the points. The finished graph looks like this.



You can see that as the numbers for the height get larger, the numbers for the speed also get larger. That means that when the car started at the top of the ramp its speed was faster than when it started at the middle or the lower part of the ramp.

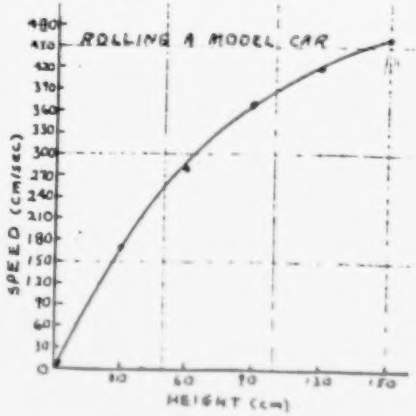
Look at the part of the graph near the origin. What do you suppose would happen if you started the car at a height of 0 centimeters? Common sense tells you that the car wouldn't roll at all. Its speed would be 0 centimeters per second. So you can plot the point for 0 centimeters height, 0 centimeters per second speed. That point is at the origin.



Measurements for very short heights and very slow speeds would be almost impossible to make, but the point at the origin helps you draw the line for your graph. You draw a smooth line through or near all the points. The point at the origin connects to the next point with a smooth line.

You can interpolate other data from this line graph, too. For example, you can tell about how fast the car will go if you start it at a certain height. Or you can tell about how high to start the car if you want it to go a certain speed.

Of course, these measurements may be very hard to make and there may be many errors in accuracy, but the graph does give you a rough picture of how the speed changes.



DEFINITIONS

Horizontal Axis

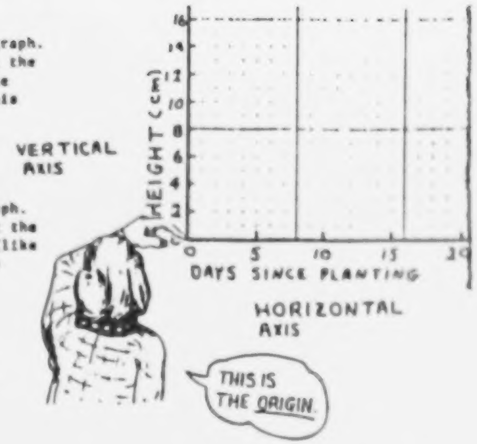
This is the bottom line of the graph. In a line graph, you usually put the measurement that you change (like months or days or time) along this axis.

Vertical Axis

This is the side line of the graph. In a line graph, you usually put the numbers that you have measured (like height or weight or temperature) along this axis.

Origin

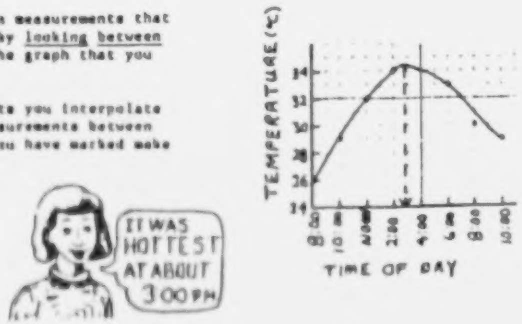
This is the point on the graph where the two axes meet.



Interpolate

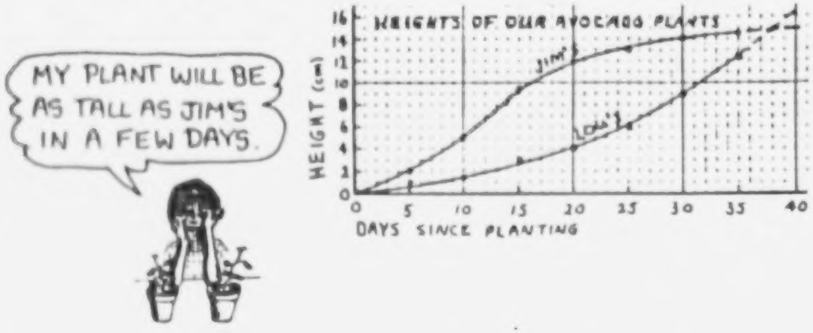
To guess certain measurements that you don't know by looking between the points on the graph that you have measured.

A line graph lets you interpolate because the measurements between the ones that you have marked make sense.



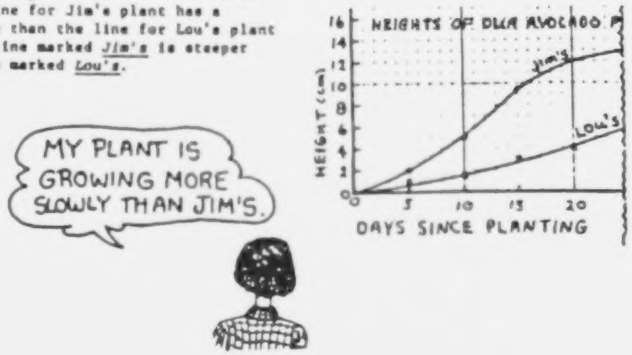
Extrapolate

To guess certain measurements beyond the ones that you know by looking at the pattern of the points on the graph.



Slope

This is the steepness of a line. In this graph, the line for Jim's plant has a greater slope than the line for Lou's plant because the line marked *Jim's* is steeper than the line marked *Lou's*.



THINGS TO KEEP IN MIND ABOUT LINE GRAPHS

IS A LINE GRAPH THE BEST GRAPH TO SHOW YOUR DATA AND ANSWER YOUR QUESTIONS?

- Are both parts of your data measurements?
- Do you want to find out how something is growing or changing?

If your answer to both questions is "yes," a line graph is probably a good graph to make.

If you answered "no" to either question, you might want to make another kind of graph. The booklets "How To" Choose Which Graph to Make for One Set of Data and "How To" Use Graphs to Compare Two Sets of Data might help you find a better graph for your data.

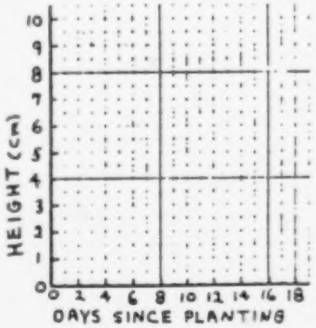
THINGS TO REMEMBER WHEN YOU DRAW YOUR LINE GRAPH

1. Draw the axes carefully. Follow the lines of the graph paper. Write what each of the axes stand for.

2. Put the measurement that you change along the horizontal axis. Put the thing that you are measuring along the vertical axis.

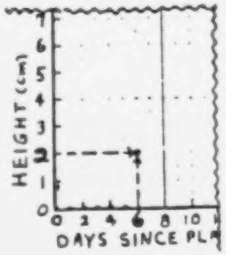
3. Write the numbers along the lines, not in the spaces. The tick marks will show what lines the numbers stand for.

4. If you don't have enough room on the graph paper, make each space stand for a difference of more than one unit of measure.



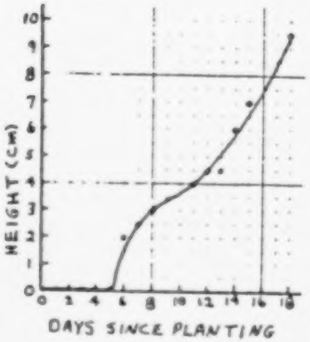
5. To plot a point, go over to the number on the horizontal axis and then up to the number on the vertical axis.

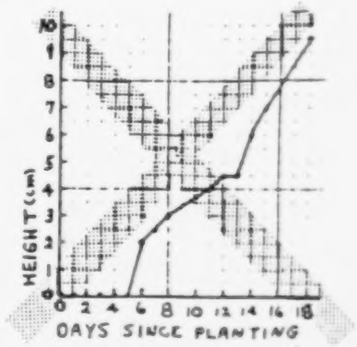
ON DAY 6 IT WAS 2 CM TALL.



6. Be sure to have enough points so that you can tell what the pattern looks like.

7. Draw a smooth line that goes through all or nearly all of the points on your graph. Don't make sharp bends. Because there are small errors in all measurements, some of the points may not be right on your line. If some points look as if they fall way outside the pattern, check your measurements again.





8. Try to figure out what the graph tells you. Can you use interpolation to guess what might be happening between the points that you have plotted? Can you use extrapolation to guess what might happen beyond the points that you have plotted?

edc This material is based upon research supported by the National Science Foundation under Grant No. SE[illegible]01071. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.
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